§6. Effects of Surface Modifications on Deuterium Retention in F82H and EUROFER Exposed to Low Energy Deuterium Plasmas

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Reduced Activation Ferritic/Martensitic (RAFM) steels, such as F82H and EUROFER, are candidate materials for fusion DEMO reactor. To understand bulk fuel retention and tritium inventories of plasma-facing materials in DEMO, analyses of samples exposed to deuterium plasmas are essential. In this study, RAFM steel samples are exposed to low energy deuterium plasmas and the effects of surface modifications on deuterium retention is elucidated.

RAFM steels, F82H (8Cr-2W) and EUROFER (9Cr-1W), were bombarded with steady-state deuterium plasmas under conditions relevant to the first wall environment using the PlaQ facility [1]. The ion bombarding energy was set to 115 eV by applying a negative DC-bias onto the target assembly. The surface temperature of the samples during plasma exposure was measured by thermocouples and an infrared camera. It was set at 450 K. Applied deuterium fluences ranged from about 10^{23} to 10^{25} D/m^2. After the plasma exposures the samples were analyzed with nuclear reaction analysis (NRA), Rutherford backscattering spectroscopy (RBS), field emission scanning electron microscopy (FE-SEM), X-ray photoelectron spectroscopy (XPS).

Deuterium retention in the steels determined by NRA is shown in Fig.1. NRA was done using D (He^3, p) ^4He reaction at different energies, 690 keV, 1200 keV, 1800 keV, 2400 keV, 3200keV and 4000 keV, respectively. Sufficient intensities of deuterium retentions in the steels are only observed at 690 keV by NRA and mainly deuterium retentions are observed at the surface and further below the surface retention is very low or below the detection limit, respectively. Deuterium retention is of the order of 10^{18} to 10^{19} D/m^2 and the difference between F82H and EUROFER is almost negligible. Surprisingly the fluence dependence shows that deuterium retention at a D fluence of 10^{23} D/m^2 is higher than that above 10^{24} D/m^2. Surface morphology is clearly changed with increasing D fluence, e.g., grain-boundaries become more clearly visible due to erosion by ion bombardment as shown in Figs. 2. Also the surface composition changed after low energy deuterium plasmas exposures, e.g., the W concentration is enriched in comparison with that of the original ferritic steels as shown in Fig.3. Because the D retention in these samples happens dominantly at the surface in a depth of much less than 1μm, we conclude that D retention in F82H and EUROFER is related to such surface modifications occurring under low energy plasma exposure.

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1) A. Manhard et al., Plasma Sources Sci. Technol (2011) 20 015010.

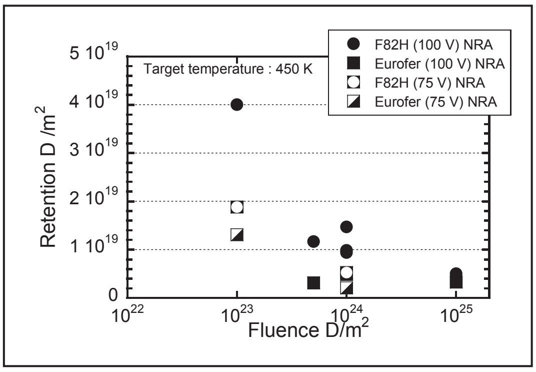

Figure 1 Fluence dependence of deuterium retention in F82H and EUROFER targets after deuterium-plasma bombardments in the Pla-Q Facility. Target temperatures are 450 K.

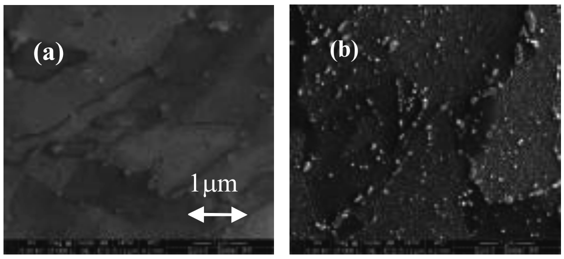

Figure 2 Surface morphologies of EUROFER measured by SEM. (a) deuterium fluence of 10^{23} D/m^2 and (b) deuterium fluence of 10^{25} D/m^2.

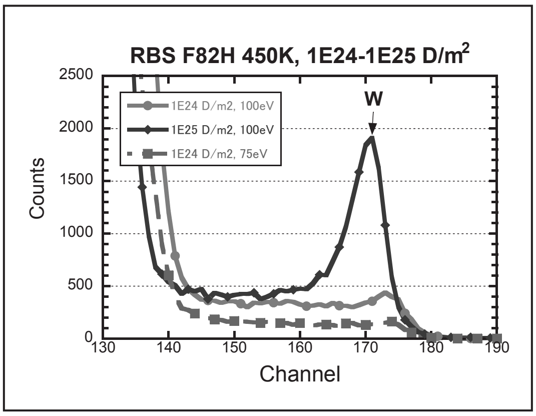

Figure 3. Surface composition on F82H targets analyzed by RBS.