§6. Damages of Low-activation Ferritic Steel Alloys Irradiated by Helium Plasmas

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Reduced Activation Ferritic/Martensitic (RAFM) steels, such as F82H, 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) was 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. Target specimens were exposed to helium pre-irradiation applied a DC-bias voltage of 200V and deuterium plasma bombardment applied a DC-bias voltage of 100V. Applied deuterium and helium fluences are 1 x 10^{24} D/m^2 and of the order of 10^{24} He/m^2, respectively. After the plasma exposures the samples were analyzed with nuclear reaction analysis (NRA), Rutherford backscattering spectroscopy (RBS), transmission electron microscopy (TEM) after focus ion beam (FIB) treatment with energy dispersive X-ray spectrometry (EDX).

Deuterium retention in the steels determined by NRA is shown in Fig.1. NRA was done using D (He^3,p)^{4}He reaction at different energies, 690 keV, 1200 keV, 1800 keV, 2400 keV, 3200keV and 4000 keV, respectively. Amounts of deuterium retention are of the order of 10^{18} to 10^{19} D/m^2 at the near top surface region using an energy of 690 keV. Target samples with helium pre-irradiation show higher deuterium retentions to compare with without helium pre-irradiations. The difference between F82H and EUROFER is almost negligible.

Figure 2 shows cross-section images after FIB treatment measure by TEM-EDX. Using mapping images of EDX, depth profiles of tungsten (W) are shown. On the image of W, a region with higher counting is shown and this thickness is about 5 nm at the top surface. From a comparison with W and other species, such as iron (Fe) and chromium (Cr), Fe and Cr show lower intensities at the top surface. A reason of this difference is due to a selective sputtering of iron and chromium. In this specimen,. a surface roughness was measured about 200 nm with a coral structure. At a convex structure at the top surface higher counting of W was observed and it is not observed at a dint structure into damaged regions from the top surface until 200 nm.

Hence, surface morphologies after helium plasma bombardments were changed to compare with that after deuterium plasma bombardments. Coral structures are observed on a plasma facing side. Each length of coral structure is less than 200 nm.

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

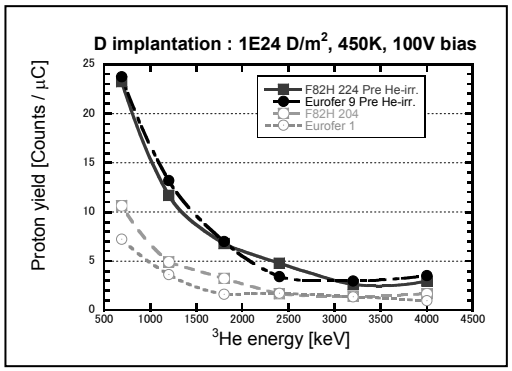

Figure 1 Deuterium retentions in F82H and EUROFER targets exposed to helium pre-irradiation and deuterium-plasma bombardments in the Pla-Q facility. Target temperatures are 450 K.

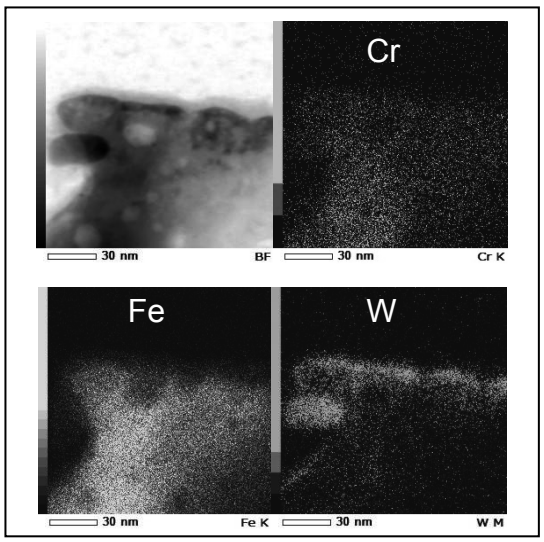

Figure 2 Cross-section images measured by TEM-EDX of F82H.