§5. Edge-plasma Interactions with Low-activation Ferritic Steel Alloys

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In a future DEMO reactor, such as FFHR [1], the first wall and the vacuum vessel have to be made of low activation materials with low induced radioactivities. Ferritic steel alloys, such as F82H (8Cr-2W), is a candidate as a low activation material. In this study, the hydrogen retention in a low activation ferritic steel alloy, F82H, and SUS316 is studied. The steels were exposed to low energy hydrogen plasma in Vehicle-1 [2] to demonstrate their first wall. Their desorption rates and surface characterizations are reported.

Target samples, F82H, were irradiated up to fluencies of 4 x 10^{18} – 9 x 10^{18} hydrogen plasma in Vehicle-1. The surface of F82H was treated by mechanical polishing to a mirror finish and then cleaned with acetone. From surface characterizations of F82H measured by XPS, oxide thickness and other impurity layers did not change before or after plasma bombardment as shown in Figs.1. In this experiment, influences of surface contamination and oxide layers were minimized, and it was considered that hydrogen was trapped in the target samples themselves.

Figure 2 shows retained hydrogen gases excluded background pressure in F82H. Different fluencies and their maximum target temperature measured by thermocouple are shown. Two distinctive desorption peaks were shown at approximately 400℃ and 500℃. These peaks suggest that the hydrogen trapping site in F82H was similar to the target samples in the plasma exposed and as-received F82H conditions. In this experiment, two kinds of trapping sites are considered. One of the trapping sites is considered an initial trapping site of the material; these have been attributed to inner defects. Other trapping site is located on the surface of target sample due to damage of plasma bombardment, such as displacement damage.

Figure 3 shows a comparison of retained hydrogen by plasma bombardment and deuterium by ion bombardment [4]. If reflection efficiency is 0.5 in steels, target samples irradiated up to fluencies of 4 x 10^{18} - 9 x 10^{18} hydrogen plasma in Vehicle-1 and the amount of retained hydrogen has been found to be 0.6 x 10^{15} – 2.5 x 10^{15} atoms/cm^2 in F82H. Hydrogen desorption for F82H and SUS316 as reference data were comparable. Differences between air exposure and plasma bombardment were reported that showed that SUS316 under air exposure retained H and D as much as five times more than did F82H. The total amount of retained H and D from plasma bombardment and ion bombardment was obtained, showing that similar amounts were retained in both F82H and SUS316. At air exposure levels, retained H and D in SUS316 were five times larger than levels seen in F82H. Both alloys also show different characterizations. A reason for the different retained amounts between as-received and plasma bombardment was considered depending on the saturation level of trapping gasses. In this experiment, as shown in Fig. 2 and Fig. 3, the retained hydrogen amount was changed by different fluencies. At present, the saturation level of hydrogen trapping sites in F82H was not clear. Toward the future fusion reactor design in DEMO, controlled wall/material temperatures are required. Plans to improve the sample stage have been designed and produced. This work is supported by NIFS budget UFFF028.

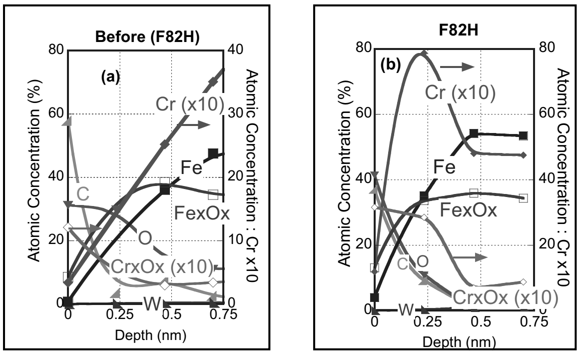

Fig.1 Depth profiles of atomic compositions with metal oxide at near the top surface. (a) F82H and (c) F82H after exposed to plasma.

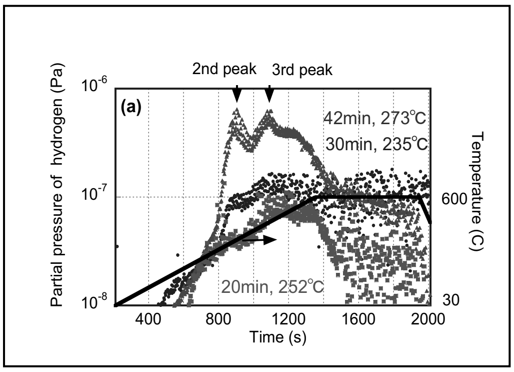

Fig.2 Thermal desorption spectra of gases containing hydrogen for F82H exposed to hydrogen plasma.

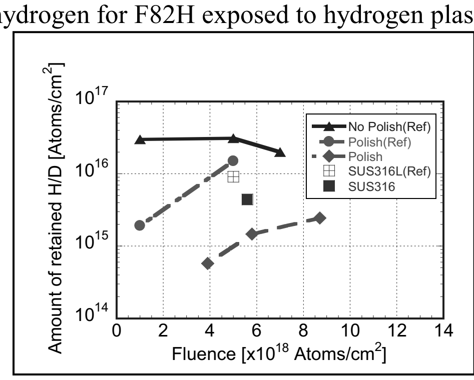

Fig.3 Retained amount of hydrogen [3] / deuterium [4] in F82H and SUS316.

1) S.Sagara et al., Fusion Engineering and Design **83** (2008) 1690-1695.

2) Y. Hirooka et al., J. Nucl. Mater. **337-339** (2005) 585-589.

3) N.Ashikawa et al., ICFRM-15 conference (2011).

4) K.Yamaguchi, et al, J. Vac. Soc. Jpn. (2003) 449.