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Surface characterizations of low-activation ferritic steel alloy exposed to plasma (2)

低放射化フェライト鋼へのプラズマ暴露による表面特性変化に関する研究（２）

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A low activation ferritic steel, F82H (8Cr-2W), was exposed to hydrogen plasma in Vehicle-1. Oxide and other impurity layers with a thickness of less than 1 nm have been observed both before and after plasma exposure in F82H. In the case of target samples irradiated up to fluencies of 7-17x10^{18} hydrogen plasma in Vehicle-1, the amount of retained hydrogen has been estimated to be 0.9-11x10^{15} atoms/cm^2. This amount is comparable to that in SUS316. Two trapping sites were observed and were considered to be inner defects.

1. Introduction

It is widely recognized in the fusion research community that the extensive use of low-activation alloys is of critical requisite for the structural and plasma facing components of future DEMO, such as FFHR [1]. Worldwide efforts on the evaluation of candidate materials are currently in progress because the successful candidate is envisaged to be used for the plasma-facing side of the blanket structure. However, it is also true that little has been known about edge-plasma interactions with these alloys such as surface modifications and particles retention. In previous studies, the JFT-2M tokamak [2] and related material R&D groups [3] in JAEA have carried out material characterizations, such as outgassing, magnetization effects and oxide/impurity contaminations. But investigations of plasma wall interactions, such as surface characterizations of oxidation/impurities and retained gasses, were not sufficient performed yet.

In this work a low activation ferritic steel alloy, F82H (89at%Fe, 8at%Cr, 2at%W, 0.1at%C) developed by Japan Atomic Energy Agency (JAEA), has been bombarded with steady-state hydrogen plasma under some of the conditions relevant to the first wall environment, using the VEHICLE-1 facility [4].

2. Experiment

The Vehicle-1 facility employs a 1 kW 2.45 GHz ECR plasma source which can generate steady state plasmas. These plasmas are magnetized at around 300 G, flowing linearly down to interact with the target samples. The surface temperature of target samples were measured by a thermocouple, and plasma parameters, such as an electron density, an ion flux, and electron and ion temperatures, were measured by a movable Langmuir probe.

The plasma density is 3~5x10^9 cm^{-3} and the electron temperature is 3-4 electron volts, resulted in the ion flux of the order of 10^{16} ions $s^{-1}cm^{-2}$. The ion bombarding energy is set at 100eV by applying a negative DC-bias onto the target assembly.

Two target samples were used in this study. One is a ferritic steel alloy, F82H, and the other is an austenitic stainless steel (SUS) 316 (18Cr-8Ni), whose sizes as the targets are 10 x 10 x 1 mm. The surface in F82H was treated by a mechanical polishing with mirror finished surface and the surface in SUS316 was treated by electropolishing. After these polishing, an acetone cleaning was done for the both sanples and were installed in TDS system. In the first TDS, outgassing processes were done to reduce residual gasses of as-received and surface-treated samples.

The chemical bonding on the surface was analyzed by X-ray Photoelectron Spectroscopy (XPS) with Mg X-rays of 400W. An argon ion gun is used to etch the target samples for depth profiling with the beam voltage of 4 kV.

Retained gasses in target samples are measured by thermal desorpstion spectroscopy (TDS). An infrared heater is located at the upper side of this

system and a quartz rod assists a heat transfer from heater to the target samples located on the bottom side. These samples were heated from room temperature to 873 K with a ramp rate of 0.48K/s. A quadrupol mass spectrometer (QMS) measured the partial pressures.

3. Results and summary

Figures 1 show atomic concentration and their rations of metal oxides. Metal oxides of chromium and iron are also plotted in this figure. Compositions of oxides were calculated by a fitting analysis and two kinds of ratios, without oxide and with oxide were obtained. At the depth of 0.75 nm from the top surface in Figs.1, iron oxides seem to still remain to about 30-40%. This can be a reason why high background intensities were remained at higher bonding energy region from the iron peak. By comparison of F82H before and after the plasma exposure, the peak positions of iron and chromium dies not change significantly by the exposure. There data indicates a sputtering and impurity contaminations during plasma exposure are negligible. In addition, hydrogen trapping sites are expected to exist in this bulk target sample.

In target samples irradiated up to fluencies of 7-17x10^{18} hydrogen plasma in Vehicle-1, the amount of retained hydrogen has been estimated to be 0.9-11x10^{15} atoms/cm^2. As shown in Fig. 2, two distinctive desorption peaks at around 420 and 500 ℃ have been exhibited, which indicated the presence of trapping sites with their respective trapping energies. These temperatures are the same as the second and the third desorption temperature peaks, respectively, in a previous work in ref. 3. From surface characterizations on F82H measured by XPS, thicknesses of oxide and other impurity layers did not changes by plasma exposure and these thicknesses were less than 1nm. In this experiment, influences of the surface contamination and oxide layers is limited but the bulk trapping sites, presumably bulk residual defects resulted in the peaks.

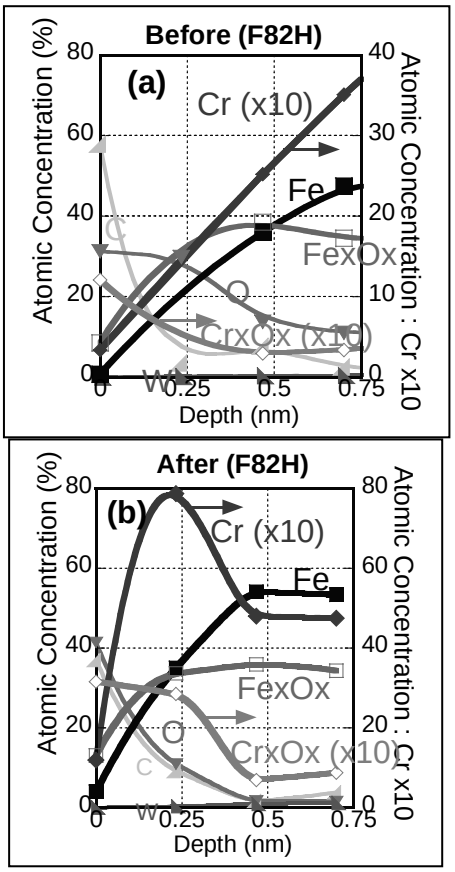

Fig.1. Atomic concentrations on the surface in F82H (a) before and (b) after plasma exposure.

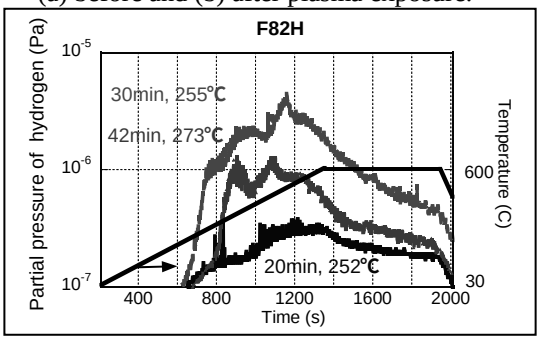

Fig.2. Partial pressures of hydrogen with different

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