§23. Study on Hydrogen Isotope and Helium Behavior in Reduced Activation Ferritic/martensitic Steel during Mixed Plasma Irradiations

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Reduced activation ferritic/martensitic steel (F82H) is a promising structure material of blanket in ITER and a demo reactor, such as FFHR. The blanket structure material is exposed to fuel hydrogen during plasma operation and part of hydrogen is retained in the material. From the point of view of tritium inventory and tritium safety, it is important to investigate hydrogen retention behavior. In addition, helium (He) produced by D-T reaction is implanted into plasma-facing wall in a demo reactor, which should influence the hydrogen retention behavior. In this study, F82H was exposed to plasmas of a mixture of hydrogen and He using Vehicle-1 device at NIFS, and the effect of helium irradiation on hydrogen retention behavior was investigated.

Before plasma exposure, the F82H samples were annealed in vacuum at 873 K. During the plasma exposure in Vehicle, bias voltages of -100 V and -200 V were applied to the samples to implant ions. The plasma density and electron temperature in this experiment were approximately $10^{10}/cm^3$ and a few eV, respectively. After the plasma exposure, the desorption behavior of retained hydrogen was investigated with thermal desorption spectroscopy. Also, in order to evaluate the relationship of hydrogen desorption behavior and irradiation damages, the change of micro structure caused by the plasma exposure was observed by transmission electron microscope, TEM.

Thermal desorption spectra of H_2 after plasma exposures is shown in Fig.1. After exposing to pure hydrogen plasma, two main peaks appeared at 310 and 470 ^oC, which would be owing to release of hydrogen trapped at naturally existing trap sites, such as grain boundary, point defects and dislocation. In the case of hydrogen plasma exposure followed by He plasma exposure with -100 bias voltage, the spectra was very similar to that of pure hydrogen plasma exposure. However, in both cases of a mixture (H_2+He) plasma exposure and hydrogen plasma exposure following by He irradiation exposure with bias voltage of -200 V, desorption rate in the temperature range between 200 and 600 ^oC significantly increased. The micro structure of F82H after He plasma exposure with bias voltage of -100 V, mixture plasma exposure and H_2 plasma irradiation following He pre-irradiation (-200V) are shown in Fig.2. After He plasma exposure (Fig.2 (a)) and mixed plasma exposure (Fig.2 (b)), bubbles with size of 1-5 nm in diameter was observed in depth less than 40 nm. After hydrogen plasma exposure (-100 V) following helium plasma exposure with bias voltage of -200 V, bubbles and voids with size of approximately 15 nm was observed in the depth less than 20 nm, and smaller bubbles were also produced at more deeper regions. The hydrogen trapped in such large bubbles and voids might be responsible for the hydrogen desorption in temperatures between 200 and 600 ^oC in the TDS spectra (Fig.1) in the case of He pre-irradiation with -200 bias voltage. However, in the case of mixture plasma exposure (Fig.2 (b)), such large bubbles and voids were not observed although hydrogen desorption in temperatures between 200 and 600 ^oC in TDS spectra (Fig.1) was observed. One of the possible reasons for that is that He could knock-on the retained H to deeper region and the H could be retained in deeper regions, compared to pure hydrogen plasma exposure case.

The result obtained in this experiment indicated that He implantation into F82H can greatly influenced the hydrogen retention behavior in a demo reactor.

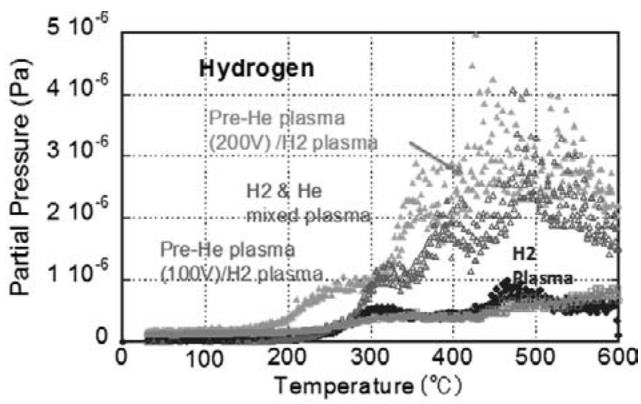

Figure 1 Thermal desorption spectra of H_2 in F82H.

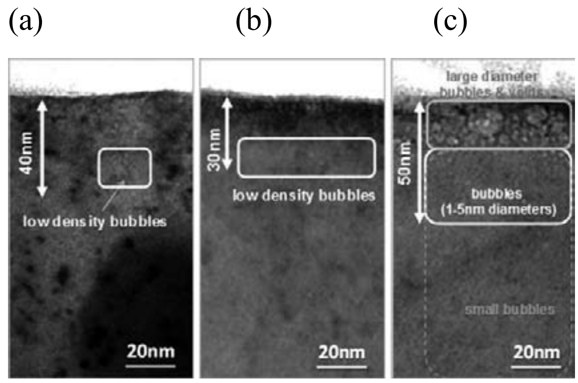

Figure 2 Micro structure of F82H after (a) He plasma (-100V), (b) H_2 and He mixed plasma and (c) pre He plasma (-200V) /H_2 plasma irradiation.