§39. Plasma-surface Interactions of Reduced Activation Ferritic/Martensitic Steel

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Reduced activation ferritic/martensitic (RAFM) steels such as F82H and Eurfer97 steels are potential candidates for structural materials of tritium breeding blankets of fusion reactors. Those steels may be used also as the first wall materials in selected areas in the reactor core with moderate particle and heat loads. To understand the interactions of the steel surfaces with the plasma in a fusion reactor, the authors examined the change in surface compositions and morphology of F82H steel after exposure to low-energy, high-flux D plasma at various temperatures.[1)] Measurements of hydrogen isotope retention after damaging with high-energy heavy ions to simulate neutron irradiation effects were also performed.[1,2)] Significant enrichment of heavy alloying elements, i.e. W, was observed due to the preferential sputtering of Fe.[1)] In addition, the surface morphology was sensitively dependent on temperature; a column-like structure was formed at around 460 K and a fiber-like nanostructure was developed at around 773 K.[1)] The heavy ion irradiations resulted in significant increase in the retention of deuterium and tritium due to trapping effects of radiation-induced defects.[1,2)] However, the detailed mechanisms underlying the surface modification and the trapping have not been clarified. The objectives of this study are to analyze the microstructures of plasma-exposed and ion-irradiated F82H steel for better understanding of the mechanisms underlying the surface modifications and the trapping. In this year, TEM observation of ion-irradiated samples was performed.

The samples used were plates of F82H steel (10×10×0.5 mm). Those specimens were mechanically polished and finished like a mirror. Then 20 MeV W ions were irradiated at room temperature to 8×10^{17} ions m^{-2}. According to the calculation using the SRIM[3)] program, the damage level reached 0.54 displacement per atom (dpa) at the Bragg peak situated at the depth of 1.8 μm. The displacement energy was set to 25 eV in this calculation. The samples thus prepared was exposed to D_2 gas at pressure of 0.1MPa and temperatures of 473 and 573 K. Then the depth profiles of D were analyzed using a nuclear reaction analysis. The cross-sectional observation using a transmission electron microscope (TEM) was performed after preparing small specimens using a focused ion beam (FIB) technique.

The depth profiles of D after exposure of the irradiated samples to D_2 gas are shown in Fig. 1.[1)] The accumulation of D in the damaged zone that caused by trapping effects of radiation-induced defects was observed. Lower D concentration at 573 K than 473 K was due to shift of trapping-detrapping equilibrium to detrapping side. Fig. 2 (a) shows the bright field image of the damaged zone. The damaged zone was densely decorated with dislocation loops. Annealing the sample in a TEM at 873 K resulted in growth of cavities as shown in Fig. 2 (b). This observation indicates that small vacancy-type defects invisible with TEM (such as monovacancy and divacancy) were also induced by the irradiation. It is plausible that these defects played major roles in trapping effects. Thermal desorption spectra showed two peaks at around 640 and 800 K. Detailed analysis of spectra is in progress to evaluate binding energies between the defects and hydrogen isotopes.

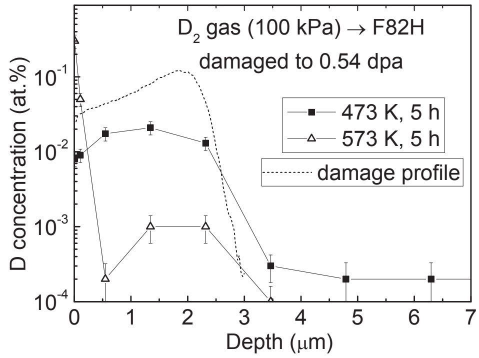

Fig. 1. Depth profiles of D in irradiated F82H steel after exposure to D_2 gas at 0.1 MPa and temperatures indicated in the figure.

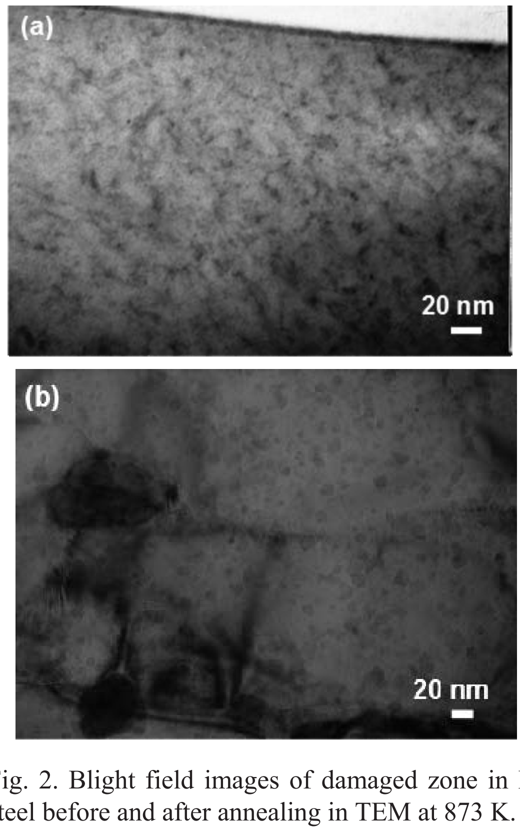

Fig. 2. Blight field images of damaged zone in F82H steel before and after annealing in TEM at 873 K.

1) Alimov, V. Kh. et al.: Phys. Scr. **T159** (2014) 014049.
2) Hatano, Y. et al.: Fusion Sci. Technol. **67** (2015) 361.