§42. Plasma-surface Interactions of Reduced Activation Ferritic/martensitic Steel

Hatano, Y., Furui, R., Yumizuru, K., Alimov, V.Kh. (Univ. Toyama), Yoshida, N. (Kyushu Univ.), Tokitani, M.

Reduced activation ferritic/martensitic (RAFM) steels such as F82H 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 a reactor core with moderate particle and heat loads. To understand the interactions of the steel surfaces with hydrogen isotope plasma, 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 [1,2]. Significant enrichment of heavy alloying elements, i.e. W, was observed due to the preferential sputtering of Fe [1,2]. 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 [1,2]. In this study, the temperature dependence of sputtering rates of F82H steel and pure Fe was examined under exposure to low-energy, high-flux D plasma because the sputtering erosion is one of the factors determining the lifetime of the steels if they are used as a first wall material. The comparison between F82H steel and Fe allows to investigate the effects of alloying elements on sputtering rates. Exposure of Fe to He plasma was also performed for comparison.

Specimens used were plates (10×10×0.5 mm) of F82H steel and Fe. Major alloying elements of F82H steel are Cr (8%), W (2%), V (0.2%) and Ta (0.02%). The specimens were exposed to low-energy (140–200 eV), high-flux (~10^{22} $m^{-2}s^{-1}$) D plasma at temperatures from 350 to 773 K in a linear plasma generator in the Japan Atomic Energy Agency (JAEA). The sputtering rate was evaluated from mass loss. The plasma consists of D^+ ions (~30%) and D_2^+ ions (~70%). Only the sputtering by D^+ ions was considered in the sputtering rate evaluation because the kinetic energy per D nucleus in D_2^+ ions was a half of that in D ions. The surface morphology of plasma-exposed specimens was examined with a field emission scanning electron microscope (FE-SEM). The exposure to He plasma was performed at ion energy of 200 eV, flux of ~1.6×10^{21} $m^{-2}s^{-1}$ and specimen temperatures up to 773 K.

Fig. 1 (a) shows the temperature dependence of sputtering rates of F82H steel and Fe under exposure to D plasma. The sputtering rate for F82H steel was clearly smaller than that of Fe. The difference between the steel and Fe can be ascribed to the enrichment of W on the surface caused by the preferential sputtering of Fe; the concentration of W on the surface was about 30 at.% in the maximum case [1,2]. The sputtering rates of F82H steel and Fe monotonously increased with increase in exposure temperature T_{exp}. The constants for proportionality of F82H steel and Fe were comparable with each other, and 2.6×10^{-5} and 2.8×10^{-5}, respectively.

As previously reported [1,2], the fiber-like nanostructure was developed for F82H steel at 773 K. However, the development of the nanostructure was not observed for Fe. The comparable constants for proportionality for the steel and Fe indicates that the temperature dependence of sputtering rate is insensitive to surface morphology.

The temperature dependence of sputtering rate of Fe under He plasma exposure is shown in Fig. 1 (b). The rate of sputtering by He ions was larger than that by D ions due to larger mass of He. Interestingly, the sputtering rate under exposure of He plasma also showed clear temperature dependence, and it monotonously increased with increase in temperature, as observed for D plasma. The mechanisms underlying the temperature dependence of physical sputtering has not been fully understood. The systematic study with metals having different physical properties is currently under preparation.

Although the sputtering rate of F82H steel by D ions was clearly lower than that of Fe, the difference was not very big; a factor of 1.5 or less. Further investigation is required for more pronounced reduction of sputtering rate.

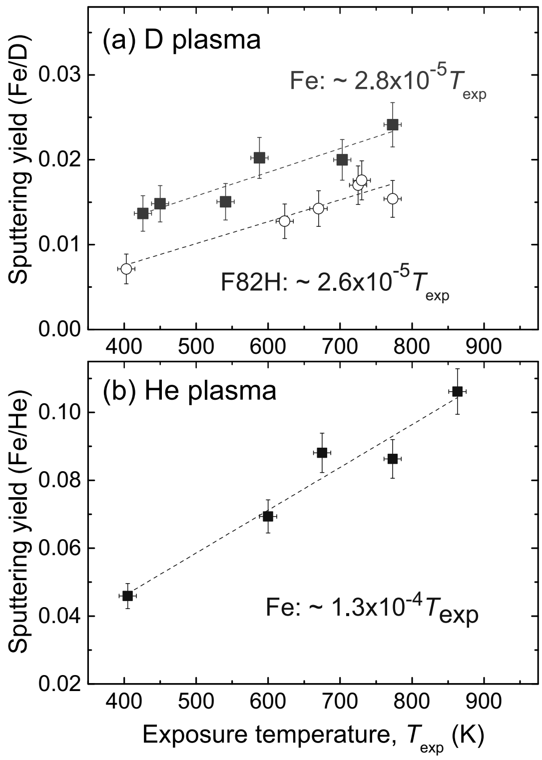

Fig. 1.Temperature dependence of sputtering rates of H82H steel and Fe under exposure to (a) D plasma and (b) He plasma.

1) Alimov, V. Kh. et al.: Phys. Scr. **T159** (2014) 014049.
2) Alimov, V. Kh. et al.: Nucl. Mater. Energy **7** (2016) 25.