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酸化エルビウム被覆の微細構造と重水素透過挙動に対する鉄イオン照射効果
Effect of iron-ion irradiation in microstructure and deuterium permeation behavior on erbium oxide coating

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1. Introduction

Control of tritium migration in a fuel system is a significant challenge for the establishment of a D-T fusion reactor. Erbium oxide (Er_2O_3) coatings have been investigated as a tritium permeation barrier which enables reduction of tritium permeation without change of structural materials [1,2]. However, the number of papers investigating tritium migration in irradiation environment is limited, and the irradiation effect on permeation is unclear. In this study, deuterium permeation through Er_2O_3 coatings damaged by iron-ion (Fe^{3+}) irradiation at elevated temperature was examined in order to elucidate the effects of irradiation damage introduction with annealing on hydrogen isotope permeation.

2. Experimental

Er_2O_3 coatings with the thickness of 1 μm were fabricated on reduced activation ferritic/martensitic steel F82H (Fe-8Cr-2W) plate substrates by filtered vacuum arc deposition. Fe^{3+} irradiation was performed using the 1.7 MV tandem accelerator DuET at Kyoto University. The ion energy was 6.4 MeV, and the sample was heated at 600 ºC during irradiation. The irradiation damage was introduced with the flux of 2.1×10^{15} Fe^{3+} m^{-2} s^{-1} and the fluence of 1.8×10^{17}–1.8×10^{19} Fe^{3+} m^{-2}, corresponding to the displacement damage concentration of 0.01–1 dpa. Deuterium permeation measurements were carried out using a gas-driven permeation apparatus described in detail in Ref. [2]. Cross-sectional grain structure of the coatings was observed by transmission electron microscopy (TEM) with selected area electron diffraction (SAED).

3. Results and discussion

Fig. 1 shows temperature dependence of deuterium permeability for damaged Er_2O_3 coatings. The coatings showed one or two orders of magnitude different permeabilities at 300–500 ºC; however, the permeabilities became comparable and lower than that of unirradiated one at 550–700 ºC, indicating the grain growth and the rearrangement of grain boundaries with a lower permeability. Cross-sectional TEM images with SAED patterns for the coatings before and after the permeation experiments indicated the formation of a defect-accumulated region near the interface between the coating and substrate. The region may play a role of deuterium trapping sites, leading to an increase of activation energies of permeation and diffusion. The stability of the region strongly depends on the irradiation condition: damage concentration and annealing time, resulting in the difference of the permeability and diffusivity in the lower temperature range.

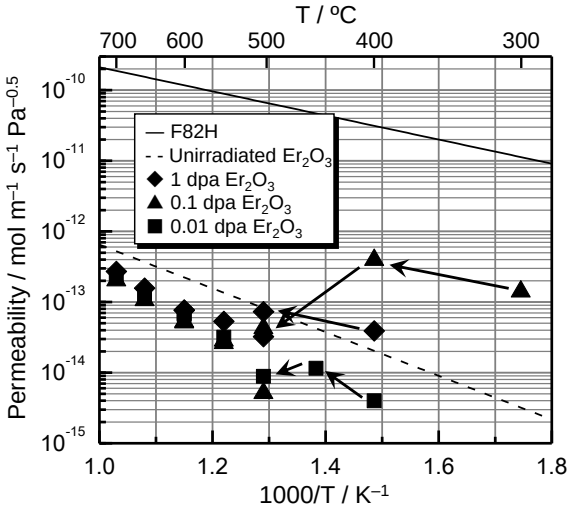

Fig. 1 Arrhenius plots of deuterium permeability for Er_2O_3-coated samples irradiated at 600 ºC.

Reference

[1] D. Levchuk, et al., J. Nucl. Mater. 367-370 (2007) 1033-1037.
[2] T. Chikada, et al., Fusion Eng. Des. 84 (2009) 590-592.