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低放射化フェライト／マルテンサイト鋼およびトリチウム透過低減被覆中の水素同位体透過挙動に対するガンマ線照射効果

Effect of γ-ray irradiation on hydrogen isotope permeation behavior in reduced activation ferritic/martensitic steel and tritium permeation barrier coating

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1. Introduction

Tritium permeation through structural materials in a fusion reactor fuel system is an important issue from the perspectives of radiological safety and suppression of fuel loss. Tritium permeation barrier (TPB), for example erbium oxide (Er_2O_3) and aluminum oxide (Al_2O_3) coatings, has been investigated for decades as a promising solution. However, tritium permeation behavior through the structural materials and TPB has not been elucidated under the actual blanket condition: high-dose-rate radiation environment. Therefore, we investigated effects of γ-ray irradiation on hydrogen isotope permeation behavior in reduced activation ferritic/martensitic (RAFM) steels and TPB coatings.

2. Experimental

Deuterium permeation through RAFM steel F82H (Fe-8Cr-2W) plate substrates and Er_2O_3 coatings prepared by filtered vacuum arc deposition and metal organic decomposition was measured. Deuterium permeation flux through the sample was detected by a quadrupole mass spectrometer (QMS) installed in a gas-driven permeation apparatus in the temperature range of 300–500 ºC [1]. A 33-TBq ^{60}Co (γ-ray flux: 1.4×10^{14}–2.3×10^{14} m^{-2} s^{-1}, absorbed dose rate of air: 3.9×10^{2} Gy h^{-1}, 4.5×10^{5} R h^{-1}) was used as γ-ray source. γ-ray was irradiated to the sample for 1 hour during deuterium permeation experiments, and then the change of permeation before, during and after irradiation was observed. Permeation behavior under several dose rates was observed by changing irradiation direction and distance between the γ-ray source and the sample.

3. Results and discussion

A typical result of temporal change of deuterium flux through the F82H substrate under γ-ray irradiation is shown in Fig. 1. Deuterium permeation flux increased after irradiation started, and decreased as much flux after irradiation finished to the similar level before irradiation. Increase of deuterium flux decreased with distance from the γ-ray source, and eventually the irradiation effect was not observed when the dose rate was lower than about 1 Gy s^{-1} (γ-ray flux: approximately 2×10^{14} m^{-2} s^{-1}). The percentage of the deuterium flux increment was not affected by irradiation temperature despite a large difference in absolute flux, indicating that γ-ray irradiation would mainly influence diffusion process which proportionally controls permeation. Increase of deuterium permeation through the Er_2O_3 coating could not be detected during γ-ray irradiation. Hence, the effect of γ-ray irradiation on hydrogen isotope permeation through the Er_2O_3 coating was exceedingly small in the present irradiation condition.

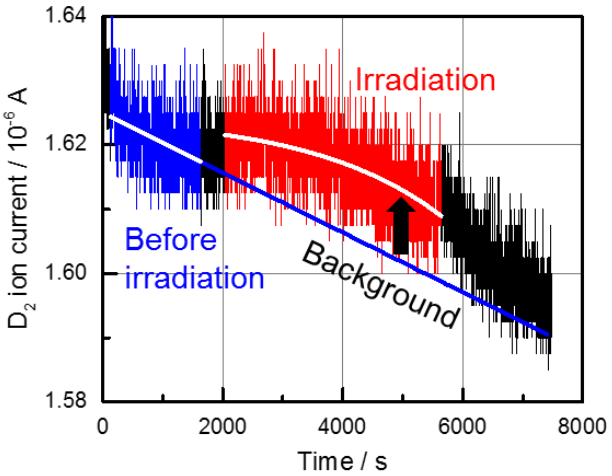

Fig. 1 Temporal change of D_2 ion current for F82H under γ-ray irradiation at 400 ºC.

Reference

[1] T. Chikada, et al., Fusion Eng. Des. 84 (2009) 590-592.