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トリチウム透過低減被覆中の水素同位体透過に対するガンマ線照射効果
γ-ray irradiation effect on hydrogen isotope permeation through tritium permeation barrier coatings

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1. Introduction

Suppression of tritium permeation through structural materials is an important issue in terms of fuel economy and radiological safety in fusion reactors; thus, ceramic coatings have been researched as tritium permeation barrier (TPB). Recently, our research on deuterium permeation through metals under γ-ray irradiation indicated that deuterium permeation increased mainly by γ-heating [1]. Similarly, tritium permeation through ceramic coatings may increase under γ-ray irradiation conditions, which will result in underestimate of tritium loss from fusion reactor blankets. Therefore, it is requisite to understand a change in hydrogen isotope permeation through ceramic coatings during γ-ray irradiation in order to evaluate the performance as TPB in actual reactors. In this study, the γ-ray irradiation effect on deuterium permeation through four kinds of ceramic coatings with different microstructures has been investigated.

2. Experimental

Reduced activation ferritic/martensitic steel F82H (Fe-8Cr-2W) plates (20 × 20 × 0.5 mm^3) were used as substrates. Four ceramic coatings with different compositions were fabricated: 1.2-μm-thick erbium oxide (Er_2O_3) coating by filtered vacuum arc deposition, 0.6-μm-thick yttrium oxide (Y_2O_3) and silicon carbide (SiC) coatings by magnetron sputtering, and 0.6-μm-thick zirconium oxide (ZrO_2) coating by metal organic decomposition.

Deuterium permeation experiments were performed using a gas-driven deuterium permeation device in a γ-ray irradiation chamber [2]. The temperature range was 250–600 ºC, and the driving pressure of deuterium to the upstream was set to 2.00×10^4–8.00×10^4 Pa. Deuterium permeation flux through the sample was detected as deuterium ion current by a quadrupole mass spectrometer (QMS). ^{60}Co γ-ray source at Shizuoka University was used for irradiation, and its radioactivity was up to 27 TBq. The γ-ray flux was estimated to be 2×10^{14} m^{-2} s^{-1}, and the absorbed dose rate of water was calculated to be 0.11 Gy s^{-1}.

3. Results & Discussion

Deuterium permeation flux through the four ceramic coatings increased during γ-ray irradiation at 250–300 ºC, but noise of the QMS was too large to detect changes in permeation flux above 300 ºC. The tendency of the γ-ray irradiation effect on the coatings was similar to that of metal materials: the effect decreased with temperature [2].

The permeation flux through the Er_2O_3 coating increased by crack formation at 500 ºC, and the γ-ray irradiation effect became similar to that of F82H substrate [1] because deuterium mainly permeated through the exposed substrate. On the other hand, the Y_2O_3 and ZrO_2 coatings started crystallization at 500 ºC with decrease of the permeation flux. Compared the results at 300 ºC, the irradiation effect decreased after crystallization, proving that the ceramic coatings reduced the deuterium permeation as well as the γ-ray irradiation effect. Although the deuterium permeation flux of the SiC coating decreased at 400 ºC, which indicated crystallization, the irradiation effect did not clearly change. For all the coatings the percentage of the permeation flux gain had a strong correlation with γ-heating.

References

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