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重イオン照射した機能性被覆の電気特性と水素同位体透過挙動との相関
Correlation between electrical properties and hydrogen isotope permeation behavior for heavy-ion irradiated functional coatings

藤原 輝[1], 法月 亮介[1], 三浦 颯太[1], 叶野 翔[2], 田中 照也[3], 居波 渉[1],
川田 善正[1], 近田 拓未[1]
Hikaru Fujiwara[1], Ryosuke Norizuki[1], Sota Miura[1], Sho Kano[2], Teruya Tanaka[3], Wataru Inami[1], Yoshimasa Kawata[1], Takumi Chikada[1]

[1]静岡大, [2]東大, [3]核融合研
[1]Shizuoka Univ., [2]Univ. of Tokyo, [3]NIFS

1. Introduction

Tritium permeation through structural materials in fusion reactor blankets is a critical issue from the perspective of fuel efficiency and radioisotope handling. Tritium permeation barrier (TPB) coatings have developed to mitigate tritium leakage using ceramics. In the actual reactors, the TPB coatings are exposed to high-dose neutrons. Our previous study elucidated the irradiation effects on microstructure and hydrogen isotope permeation behavior of TPB coatings through heavy-ion irradiation to simulate the irradiation damages introduced by neutrons. [1]. However, these analytical methods used in the previous investigation are destructive and time-consuming. As a non-destructive and simple evaluation method, electrical measurement is one of the promising methods for practical applications. In this study, aiming to develop a simple evaluation method for TPB coatings, we performed electrical measurements for ceramic coatings after heavy-ion irradiation and investigated the effects of irradiation on the coatings by comparing the results with those of conventional permeation measurements.

2. Experiments

Reduced activation ferritic/martensitic steel F82H (Fe-8Cr-2W, F82H-BA07 heat) plates were used as substrates. Zirconium oxide (ZrO_2) coatings were prepared by metal-organic decomposition with a dip-coating technique [2]. The coated samples were irradiated using 6.0-MeV Ni ions and 2.8-MeV Fe ions with a displacement damage of up to 10 dpa at room temperature. Thereafter, electrochemical impedance spectroscopy was performed in the frequency range of 1–10^5 Hz and the temperature of 200–550 ºC, and deuterium permeation measurements were also conducted using a gas-driven permeation apparatus in the temperature range of 250–600 ºC.

3. Results and discussion

Fig. 1 shows the Arrhenius plots of the deuterium permeation flux for ZrO_2 coatings with and without irradiation. In the measurements below 400 ºC, the permeation fluxes of all samples were three orders of magnitude lower than an uncoated substrate. The undamaged coating showed an order of magnitude lower permeation fluxes compared to the substrate at high temperatures, which is due to cracking of the coating. On the other hand, the irradiated coatings kept high permeation reduction performance, suggesting that irradiation made the coating less prone to cracking.

In the electrical measurements, the conductivity of the irradiated coating was up to two orders of magnitude higher than that of the undamaged one. In the presentation, relationship between deuterium permeation behavior and electrical properties will be also discussed.

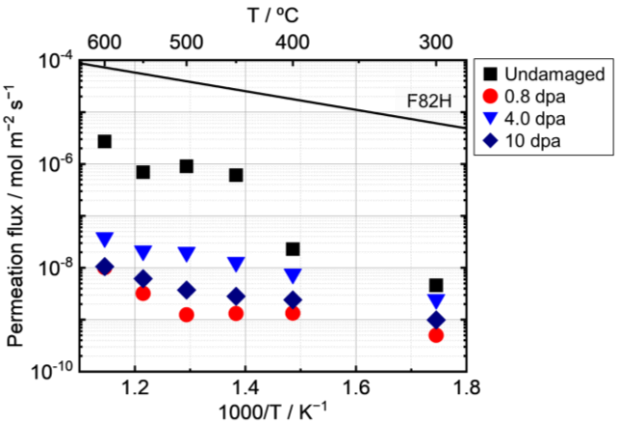

Fig. 1. Arrhenius plots of deuterium permeation flux for ZrO_2 coatings with and without irradiation.

Reference

[1] K. Nakamura et al., J. Nucl. Mater. 537 (2020) 152244.
[2] J. Mochizuki et al., Fusion Eng. Des. 136 (2018) 219−222.