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機能性セラミックス被覆の電気特性および水素同位体透過挙動に及ぼす重イオン照射影響

Heavy-ion irradiation effect on electrical properties and hydrogen isotope permeation behaviors of functional ceramic coatings

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1. Introduction

In a fusion blanket system, functional coatings have been developed to mitigate tritium permeation through structural materials, and ceramic coatings showed high permeation reduction performance. In recent years, heavy-ion irradiation tests have been conducted to simulate the radiation environment in the actual reactor. Our previous studies elucidated the irradiation effects on microstructural change and permeation reduction performance in the coating [1,2]. However, most analytical methods used to characterize these coating properties are destructive, time-consuming, and difficult to apply to actual components of the reactor. In this study, the irradiation effects on electrical properties and deuterium permeation behavior of the coatings were investigated by conducting the electrochemical impedance spectroscopy as a convenient approach and the deuterium permeation measurement as a conventional method.

2. Experiments

Reduced activation ferritic/martensitic steel F82H (Fe-8Cr-2W) plates were used as substrates. Zirconium oxide (ZrO_2) coatings were fabricated by metal organic decomposition with a dip-coating technique. The coatings were irradiated by 6.0 MeV Ni ions with a displacement damage of 0.8–4.0 dpa at room temperature. After the irradiation tests, metal electrodes were deposited on the coating surface, and electrical impedance spectroscopy was performed in the atmosphere in the frequency and temperature range of 1–10^5 Hz and 200–550 ºC, respectively. Deuterium permeation tests were carried out for the coatings using a gas-driven permeation apparatus with the deuterium driving pressure of 10–80 kPa in the temperature range of 300–550 ºC.

3. Results and discussion

Fig. 1 shows Arrhenius plots of the deuterium permeation flux for the ZrO_2-coated samples with and without irradiation. In the case of the undamaged coating, the permeation fluxes increased from 300 ºC to 450 ºC, but then showed almost the same values up to 550 ºC and increased again above 550 ºC. That indicates the microstructural change occurred at 450–550 ºC. On the other hand, those temperatures for the 0.8-dpa-damaged coating were lowered from 400 ºC to 500 ºC. This result suggests that irradiation defects would increase the mobility of grain boundary in the coating and cause the microstructural change even at relatively low temperatures.

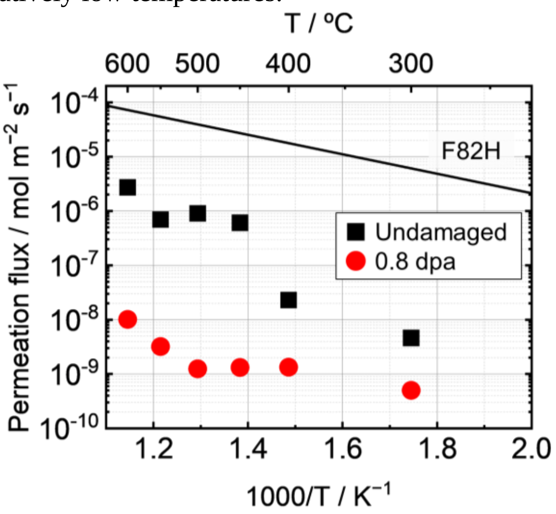

Fig. 1 Arrhenius plots of deuterium permeation flux for ZrO_2 coatings with and without irradiation.

Reference

[1] K. Nakamura et al., Fusion Eng. Des. 146 (2019) 2031–2035.

[2] K. Nakamura et al., J. Nucl. Mater. 537 (2020) 152244.