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低放射化フェライト鋼およびセラミックス被覆の水素同位体透過挙動に与えるトリチウム増殖材微小球の影響

Effect of solid tritium breeder pebbles on hydrogen isotope permeation behavior of reduced activation ferritic steel and ceramic coating

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1. Introduction

In a fusion blanket, tritium permeation through structural materials is a critical issue in terms of fuel efficiency and radiological safety. Tritium permeation barrier (TPB) coatings have been developed for several decades to solve the problems and showed high permeation reduction performance using ceramic coatings. Our previous study investigated the compatibility of the coatings in contact with solid tritium breeder pebbles [1]. However, there is a limited number of studies to investigate the corrosion effect on hydrogen isotope behavior of the coatings. In this study, deuterium permeation behavior of steels with and without ceramic coatings under exposure to solid tritium breeder pebbles was investigated to establish a database of tritium permeation in solid breeder blankets.

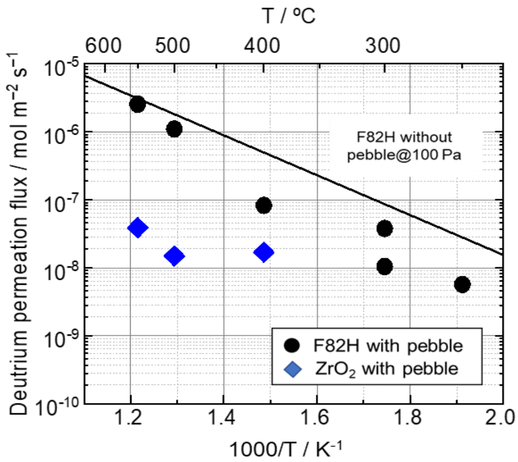
2. Experiment

Reduced activation ferritic/martensitic (RAFM) steel F82H (Fe-8Cr-2W) plates were used as substrates. A zirconium oxide (ZrO_2) coating was fabricated on the F82H substrate by metal organic decomposition. Deuterium permeation measurements were carried out using a gas-driven permeation apparatus for the F82H samples with and without the ZrO_2 coating in contact with mixture pebbles consisting of Li_2TiO_3 and Li_2ZrO_3 (LTZO). The deuterium driving pressure was 10–100 Pa, and the test temperature was 250–550 ºC.

Surface and cross-sectional observation of the samples before and after the measurements was conducted by scanning electron microscopy (SEM) with energy dispersive X-ray spectroscopy.

3. Results and discussion

Arrhenius plots of the deuterium permeation flux for the F82H and the ZrO_2-coated samples under exposure to ceramic pebbles are shown in Fig. 1. The F82H with pebbles showed an order of magnitude lower permeation fluxes at 250–400 ºC compared to that without pebbles. In the measurement at 500–550 ºC, the permeation fluxes showed values similar to that without pebbles. These results indicate a corrosion layer formed on the F82H substrate during exposure to LTZO pebbles and suppressed the deuterium permeation at low temperatures. However, the layer would be broken by thermal stress or reduced by deuterium at high temperatures, leading to the increase in the flux. The permeation flux of the ZrO_2-coated sample showed two orders of magnitude lower than that of the F82H under the same condition. Besides, no significant degradation in the ZrO_2 coating was confirmed by SEM observation after the measurements, indicating the ZrO_2 coating is compatible with the LTZO pebbles under the present condition.



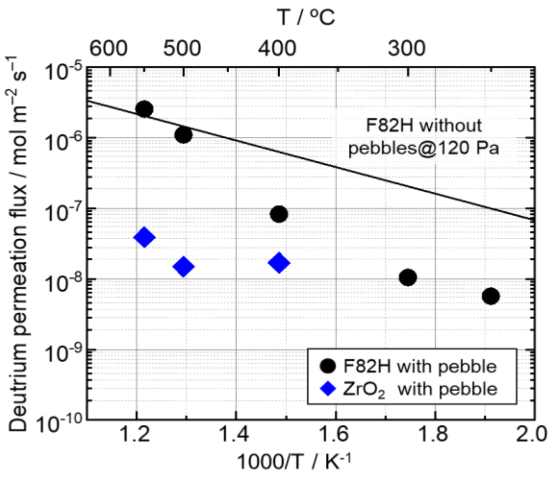


Fig. 1 Arrhenius plots of deuterium permeation flux for F82H and ZrO_2-coated samples under exposure to ceramic breeder pebbles.

Reference

[1] T. Chikada et al., Corros. Science 182 (2021) 109288.