01Dp06

ガンマ線照射と同位体交換反応によるセラミック被覆からのトリチウムの除去

Tritium removal from ceramic coating by gamma-ray irradiation with isotopic exchange

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1. Introduction

In a D-T fusion reactor blanket system, precise prediction and evaluation of hydrogen isotopes (HI) retention into structural materials are needed to establish appropriate HI handling in terms of fuel efficiency as well as radiological hazard. Another indispensable prerequisite in the reactor is to clarify neutron and gamma-ray irradiation effects, which may have an impact in the HI retention behavior. Besides, it is expected that an interaction of gamma-ray irradiation with HI exchange may affect the HI retention since deuterium and tritium exist in the blanket at the same time during the operation. In this study, a new method of tritium removal was investigated through the measurements of HI concentrations in ceramic-coated samples after exposure to HI with and without gamma-ray irradiation under different atmospheres.

2. Experimental

Reduced activation ferritic/martensitic steel F82H (Fe-8Cr-2W, F82H-BA07 heat) plates were used as substrates. In this work, two kinds of ceramic coating were selected: zirconium oxide (ZrO_2) and yttrium oxide (Y_2O_3) coatings. The ZrO_2 coating with a thickness range of 700–900 nm and the Y_2O_3 coating with thicknesses of 650 nm and 3.7 μm were fabricated by metal organic decomposition and radio-frequency magnetron sputtering, respectively. These samples were exposed to 8.9-Torr tritium for 3 hours at 500 ºC. After tritium exposure, the samples were separately stored under argon gas at atmospheric pressure and 80-kPa deuterium for about a month. After that, the amount of tritium retained in the ceramic-coated samples were examined by tritium imaging plate (T-IP) technique and β-ray induced X-ray spectrometry (BIXS). As another measurement of hydrogen isotope retention without tritium, the coated samples were exposed to 80-kPa deuterium for 50 h at 500 ºC, and then were irradiated by gamma-ray with the dose rate of 0.45–2.0 Gy/s at room temperature using a ^{60}Co gamma-ray source. After that, the concentrations of deuterium and protium in the samples were analyzed using a nuclear reaction analysis with ^{15}N ion beam (^{15}N-NRA).

3. Results and discussion

Table shows T-IP results for the samples exposed to tritium. From the obtained β-ray signals, the ZrO_2-coated samples possessed an activity concentration of approximately 140 GBq/cm^3, and the concentration was 4 times higher than that of the Y_2O_3-coated samples. After two months, the activity concentration decreased in the samples stored under argon gas rather than those stored under D_2 gas, suggesting that the retention behavior varied with hydrogen isotope partial pressure in the environment.

The ^{15}N-NRA results showed that detected HI signals from ZrO_2-coated samples decayed with ^{15}N ion dose, regardless of gamma-ray irradiation. That indicates the amount of HI decreased due to diffusion, which was promoted by energy transfer from ^{15}N ions. In addition, the amount of movable HI increased for all the gamma-ray irradiated samples, suggesting that gamma-ray made retained HI in the ZrO_2 coatings movable. This effect may contribute to the development of tritium removal technology in D-T fusion reactors.

In the presentation, the results of BIXS will be also discussed.

Table T-IP on standard samples, ZrO_2- and Y_2O_3-coated with and without tritium exposure

Material	Atmosphere	First measurement		Second measurement (2 months later)		Diminution percent for activity concentration / %
		Photo	Activity concentration / GBq cm^{-3}	Photo	Activity concentration / GBq cm^{-3}	
ZrO_2	Ar		140		123	12.5
	D_2		147		138	6.1
Y_2O_3	Ar		39.8		36.9	7.4
	D_2		32.3		31.2	3.4