Deuterium Permeation Mechanism through Erbium Oxide Coating for Tritium Permeation Barrier

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Suppression of tritium permeation through reduced activation ferritic/martensitic steels is a key investigation for realization of an operative fuel cycle in fusion blanket concepts. Recent years, investigations on erbium oxide (Er_2O_3) thin films have been demonstrated as a promising candidate for tritium permeation barrier [1, 2]. However, understanding of hydrogen-isotope permeation through ceramic coatings is not still enough because the permeation phenomenon consists of not only diffusion but also surface reactions such as adsorption and dissociation. In this study, the hydrogen-isotope permeation mechanism through the Er_2O_3 coating has been discussed with a physicochemical approach to the diffusion behavior and the surface reactions.

The erbium oxide coating was prepared with filtered vacuum arc deposition method on one side or both sides of JLF-1 and F82H steel disks. Deuterium permeation measurements were performed by using a gas-driven deuterium permeation apparatus. The permeability of the samples with a 2.6 μm-thick Er_2O_3 layer on one side and 1.3 μm-thick layers on both sides has been measured. Factors of permeation reduction of 10^3 and 10^4 have been evaluated respectively, which means the both-sides coated sample has one order of magnitude higher permeation suppression efficiency than that coated on one side in spite of the same effective thickness. Additionally, the activation energies of permeation through are estimated 81 and 117 kJ/mol. That indicates the surface reactions on the coating possess higher activation energies than diffusion process. Moreover, the deuterium permeation behavior has been examined with a 1.3 μm-thick coating deposited on one side facing to high and low deuterium pressure side in the apparatus. Compared to the result of the both-sides coated sample, the value of permeation reduction factor can be described not by addition but by multiplication of those of the coatings facing to the high and low pressure side. This result suggests an important finding that the deuterium permeation through the coating is not described by two-layer diffusion model and the surface behavior is dominant.

[1] D. Levchuk, et al., Journal of Nuclear Materials 367–370 (2007) 1033–1037.
[2] T. Chikada, et al., Fusion Engineering and Design 84 (2009) 590–592.