Phosphate/Oxide Multi-Layer Coating as Tritium Permeation Barrier for Ferritic Steel

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Development of permeation barrier for ferritic steel is important to mitigate uncontrolled tritium transport in fusion reactors especially for those with water-cooled blanket systems, because the recovery of tritium from water appears to be more difficult than that from other coolant such as He gas. Water-cooled blanket systems are supposed to be operated at around 300 ºC. The present authors have developed a phosphate/oxide multi-layer coating as permeation barrier [1]. This coating showed good barrier effects against H_2 permeation through type 430 ferritic stainless steel (SS430) at/below 500 ^{o}C, though degradation was observed at higher temperatures. From these view points, the barrier effects of the multi-layer coating and permeation mechanism of hydrogen were examined in detail at/below 500 ^{o}C in the present study.

The coating was formed on SS430 disks by wet-chemical methods because of their feasibility to prepare coatings on complicated geometries. A thin ZrO_2 film (50 nm) was prepared by sol-gel method, and this ZrO_2 layer was subjected to electrochemical treatments to seal open pores. Then, a layer of Mg or Al phosphate was prepared on ZrO_2 layer by dip-coating method. Total thickness of coatings was 200 nm. Permeation of H_2 was examined at driving pressures from 25 to 100 kPa and temperatures from 300 to 500 ^{o}C. The multi-layer coating showed significant barrier effects, and permeation reduction factors obtained were ca. 200, 400 and 1200 at 300, 400 and 500 ^{o}C, respectively. No noticeable difference was observed between Mg and Al phosphates. The activation energy of permeation, however, was small, and it was 18 ± 7 kJ mol^{-1}. In addition, the permeation rate was not simply proportional to square root of driving pressure but showed complicated pressure dependence. These observations indicate that open pores are still making significant contributions to permeation through the coating layer. Further improvement of barrier effects is possible by optimization of preparation conditions and consequent reduction in the density of open pores.

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[1] K. Zhang and Y. Hatano, Fusion Eng. Design, in press.