Deuterium Permeation and Thermal Behaviors of Amorphous Silicon Carbide Coatings on Steels

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Tritium permeation through structural materials in a fusion reactor blanket system is one of the most important issues because it will cause a critical fuel loss and a health hazard. Silicon carbide (SiC) is considered a promising candidate for tritium permeation barrier [1]. However, at present, there are limited results reported on hydrogen permeation through SiC coatings with a low-temperature process to keep the properties of the structural material [2]. In the present study, amorphous SiC coatings on steel substrates have been fabricated by physical vapor deposition and deuterium permeation behaviors of the samples have been measured at elevated temperatures.
The SiC coatings were deposited on austenitic SS316 and reduced activation ferritic/martensitic F82H by RF magnetron sputtering. The substrate temperatures during deposition were room temperature and up to 673 K. Microstructure and crystallinity of the coatings were examined by electron microscopy and X-ray diffraction, respectively. Deuterium permeation was measured by a gas-driven permeation system at 773–873 K.
Figure 1 shows the temperature dependence of deuterium permeability of the samples with different coating thickness. In case of the 0.4 μm-thick coating on F82H, a gradual increase of the permeability has been obtained with a temperature increase. In addition, diffusion limited regime has been confirmed by the deuterium pressure dependence of the permeation flux. On the other hand, the 3 μm-thick coating on SS316 shows a low permeability at 773 K, and then a drastic increase in the next measurement at 873 K. Besides, the permeability has not recovered when the test temperature has decreased to 773 K again. That means the coating has clearly degraded after heated up to 873 K. The reason of the degradation is considered because a large difference of coefficient of thermal expansion between the SiC coating and the SS316 substrate has resulted in an inner stress and generated cracks in the coating. This suggests that optimization of the coating thickness is important to control the inner stress.

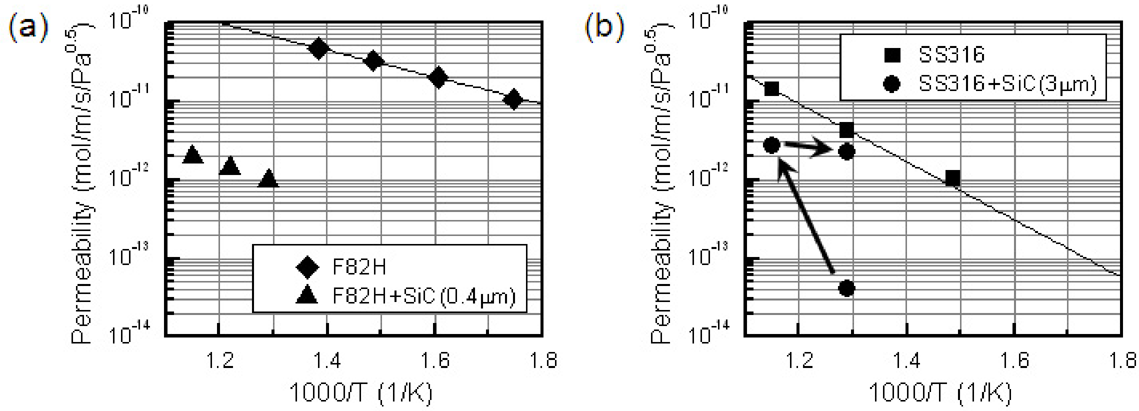

Figure 1: Arrhenius plots of deuterium permeability of SiC coatings (a) with 0.4 μm in thickness on F82H and (b) with 3 μm in thickness on SS316

[1] G.W. Hollenberg et al., Fusion Engineering and Design, volume 28, 1995, pp.190–208
[2] Z. Yao et al., Fusion Science and Technology, volume 52, 2007, pp.865–869