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トリチウム透過低減被覆中の重水素透過挙動に対するヘリウム注入の影響
Influence of helium implantation on deuterium permeation behavior in tritium permeation barrier coatings

近田 拓未[1]、中村 和貴[1]、藤田 光[2]、松永 萌暉[1]、木村 圭佑[1]、藪内 聖皓[3]、菱沼 良光[4]、時谷 政行[4]
Takumi Chikada[1], Kazuki Nakamura[1], Hikari Fujita[2], Moeki Matsunaga[2], Keisuke Kimura[2], et al.

[1]静岡大院総、[2]東大院工、[3]京大エネ研、[4]核融合研
[1]Shizuoka Univ., [2]Univ. Tokyo, [3]Kyoto Univ., [4]NIFS

1. Introduction

Control of tritium migration in a fuel system is a significant challenge for the establishment of a D-T fusion reactor blanket. Yttrium oxide (Y_2O_3) coatings have been recently investigated as a candidate of tritium permeation barrier which enables reduction of tritium permeation without change of structural materials. Moreover, the effect of irradiation damage on hydrogen permeation through Y_2O_3 coating using heavy ions instead of neutrons has been reported in our previous paper [1]. In the actual fusion reactor, however, not only irradiation damage by neutrons but also helium (He) retention by nuclear reactions and disintegration of tritium should be considered. In this study, iron (Fe) irradiation and He implantation in Y_2O_3 coatings were carried out, followed by microstructural analyses and deuterium permeation measurements.

2. Experimental

Y_2O_3 coatings with the thickness of approximately 650 nm were fabricated on reduced activation ferritic/martensitic steel F82H (Fe-8Cr-2W) plate substrates by reactive magnetron sputtering [1]. Fe^{3+} irradiation and He^{+} implantation at room temperature were simultaneously performed using the 1.7 MV tandem accelerator DuET at Kyoto University. The ion energy of Fe^{3+} was 6.4 MeV, and that of He^{+} was distributed from 0.16 to 1.0 MeV using an energy degrader. The average displacement damage concentration by Fe^{3+} and He^{+} was 0.5 and 0.2 dpa, respectively. The maximum He concentration in the coating was 2620 appm. Cross-sectional grain structure of the coatings was observed by transmission electron microscopy (TEM) with selected area electron diffraction (SAED). Deuterium permeation measurements were carried out using a gas-driven permeation apparatus described in detail in Ref. [2].

3. Results and discussion

Fig. 1 shows a cross-sectional TEM image of the Y_2O_3 coating after simultaneous Fe^{3+}/He^{+} irradiation/implantation. Numerous bubbles of less than 5 nm in diameter were observed. Since the bubbles were not observed in the coating after only Fe^{3+} irradiation, they were He bubbles. The coating irradiated by 6.4 MeV Fe^{3+} formed three layers: larger grains with voids at the top, smaller grains with few voids in the middle, and amorphous above the F82H substrate. It is suggested that the second layer was generated by energy deposition from high-energy ions, and the third layer was formed mainly by damage introduction. Compared with an unirradiated Y_2O_3 coating, deuterium permeation flux for the Fe^{3+}-irradiated and simultaneously Fe^{3+}/He^{+}-irradiated/implanted samples showed lower values at 300–550 °C due to formation of the second layer. More detail discussion on permeation behaviors will be included in the presentation.

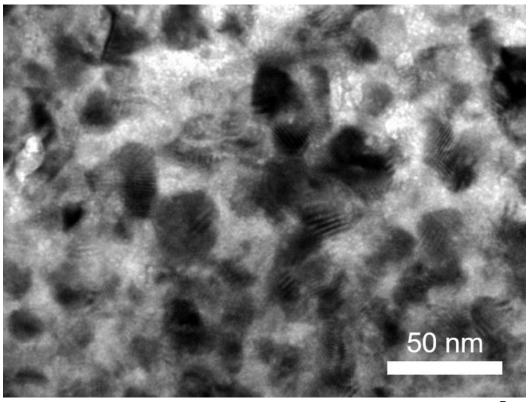

Fig. 1 Cross-sectional TEM image of Fe^{3+}/He^{+} irradiated/implanted Y_2O_3 coating.

References

[1] T. Chikada, et al., J. Nucl. Mater. 511 (2018) 560–566.
[2] T. Chikada et al., Fusion Eng. Des. 84 (2009) 590–592.