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水素同位体・ヘリウム同時照射時の低放射化フェライト鋼F82Hにおける表面形態の変化とスパッタリング率に関する研究

Surface morphology changes and erosion of F82H steel under simultaneous hydrogen and helium irradiation

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1. Introduction

In order to reduce the cost and complexity of building and operating a fusion reactor, it has been suggested that bare Reduced Activation Ferritic Martensitic (RAFM) steels should be used without any armor materials for the first wall in a fusion reactor. Lifetime is an important factor to consider for plasma facing components. The effects of simultaneous hydrogen isotope and He irradiation, however, have not been examined in any detail. Therefore, in this study we report on the surface morphology evolution and corresponding mass loss of F82H as a function of temperature under simultaneous hydrogen isotope and He irradiation.

2. Experiment

Hydrogen isotope irradiation with and without helium was performed at Osaka University using the high flux ion beam test device (HiFIT) [1]. The irradiation experiments were performed at the following temperature: 500 - 865 K. The irradiation fluence was kept constant at 1×10^{24} D(H)/m^2. In simultaneous D(H)-He irradiation experiments, He impurity % in the ion beam was estimated to be ~0.5 %. The sputtering yield was then calculated from the mass loss and total implanted hydrogen isotope fluence.

While characterization of irradiated samples was performed at NIFS by electron microscopy and ion beam analysis. The surface morphology and cross-sectional images were surveyed with FE-SEM combined with FIB. To observe nanometer He bubbles, cross sectional samples were prepared and analyzed with TEM. EDS was performed using the TEM samples to measure the elemental composition/distribution. Due to the limited spatial resolution of EDS, W enrichment at the surface was measured using RBS using an ion beam accelerator.

3. Results

The sputtering yield increased at T > 750 K for both cases, corresponding to a temperature region where large-scale surface modifications occurred. In addition, the presence of He further increases the sputtering yield. This was correlated with reduced W concentration at the surface seen in Fig 1, indicating He has an important role in W surface enrichment process. The exact mechanism requires elucidation, but formation of He bubbles or disturbance of H-induced effects to W mobility may play a role. Comparison between calculated W areal densities from mass loss measurements to RBS measurements agree within a factor of two, suggesting that hardly any W is sputtered. However at T > 750 K, the dominant process determining the sputtering yield of F82H appears to be a combination of W-enrichment and the evolving complex surface morphology.

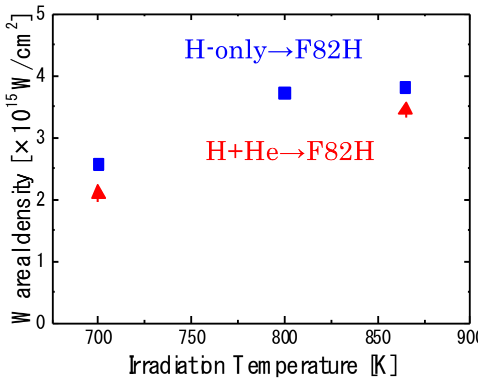

Fig 1 W areal density as function of irradiation temperature

References

[1] Ueda Y et al 2002 Fusion Engineering and Design 61 255