Effect of He on D retention in various RAFM steels

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Toward the use of RAFM (reduced-activation ferritic/martensitic) steels as a plasma-facing material (PFM) in future fusion devices, fundamental properties of RAFM steels as a PFM have been investigated in laboratory experiments. In this study, we have explored D retention in various RAFM steels (CLF-1, Eurofer, F82H, and Rusfer) exposed to plasmas (D fluence ~ 1×10^{25} m^{-2}, ion flux ~ 2×10^{21} m^{-2}s^{-1}, sample temperature ~ 373 K, incident ion energy ~ 100 eV) in the PISCES-A linear plasma device. The total D retention, R_D, was measured using thermal desorption spectroscopy (TDS), taking into account both HD and D_2 signals.

As a baseline, R_D caused by pure D plasma exposure was first measured for each material. Under the same pure D plasma exposure condition, R_D was found to depend strongly on the RAFM steels: R_D(CLF-1) ~ 1.3×10^{21} m^{-2}, R_D(Rusfer) ~ 8.0×10^{20} m^{-2}, R_D(Eurofer) ~ 7.9×10^{19} m^{-2}, and R_D(F82H) ~ 4.5×10^{19} m^{-2}. Next, simultaneous D+He mixed plasma exposure was performed with the He fluence of ~1×10^{24} m^{-2}. A reduction of D retention was seen for all the RAFM steels, but with a different reduction factor: ~18x for CLF-1, ~6x for Rusfer, ~2x for Eurofer, and ~1.5x for F82H. TDS spectra show D desorption can be separated into low (< 600 K) and high (> 600 K) temperature components. It was found that the low temperature D desorption is more sensitive to (1) the type of RAFM steels, (2) the admixture of He, and (3) the sample temperature during plasma exposure, compared to the high temperature desorption.

Microstructures of the near-surface region of the plasma-exposed CLF-1 samples were observed with TEM (transmission electron microscopy). On the surface exposed to simultaneous D+He mixed plasma, high-density cone structures with the height of ~50-100 nm were formed, and high-density He bubbles were observed both inside and under the cones. The thickness of the He bubble layer under the cones is around 15 nm. On the other hand, a drastic change was not seen on the surface exposed to pure D plasma, except the formation of low-density large cones with the height of ~200 nm, which were also formed on the simultaneous D+He mixed plasma exposed surface. The high-density He bubble layer is, therefore, considered to play a key role in reducing the D retention in the same way as for W [1, 2].

1. M. Miyamoto, D. Nishijima, Y. Ueda, et al., Nucl. Fusion **49**, 065035 (2009)
2. M.J. Baldwin and R.P. Doerner, Nucl. Fusion **57**, 076031 (2017)

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