Modeling of ExB effects on tungsten re-deposition and leakage in the DIII-D divertor*

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Mixed-material DIVIMP-WallDYN modelling, now incorporating ExB drifts, is presented that simultaneously reproduces tungsten (W) erosion and deposition patterns observed during the DIII-D Metal Rings Campaign, in which a toroidally symmetric set of W-coated tiles were installed in the carbon (C) DIII-D divertor. Since the ITER divertor will quickly evolve into a mixed W/Be environment, this work represents an important identification of physics that will affect material lifetimes and high-Z impurity leakage from the divertor to the core. These simulations suggest that ExB transport dominates over parallel force balance effects for high-Z impurities such as W in the divertor region of DIII-D. It is demonstrated that ExB drifts are required to reproduce the experimental observations, and that the spatial structure of modeled divertor poloidal ExB drifts correlates with boundaries of the observed deposition/erosion regions, with radial ExB drifts also playing an important role.

In the mixed-material environment of DIII-D, sputtering of W is suppressed by the formation of C co-deposits in regions with strong poloidal ExB drifts oriented towards the divertor target. For attached L-mode conditions and unfavorable ion grad-B drift direction, W and C co-accumulation is observed over a band ~5-8 cm outboard of the outer-strike-point (OSP) W source while little W is observed closer to the OSP [1]. In addition, W gross erosion is localized to the region outboard of the OSP, peaking ~2 cm from the strike point. Time-dependent simulations with modified ExB impurity drifts (60% of the OEDGE-calculated drift velocity) quantitatively reproduce these features, including depth-resolved W/C ratios, within a factor of 2 over ~110 seconds of accumulated plasma exposure. Including multiple re-erosion steps of deposited W in the model changes the overall re-deposition rate by over an order of magnitude, leading to a better match with the observed W deposition patterns. Qualitative agreement is also found between campaign-integrated W deposition measurements and simulations for the favorable ion grad-B drift direction, the standard mode of operation for most tokamaks. These results imply that a long-term inward radial migration of material from the outer divertor through the private flux zone may occur in future devices.

[1] W.R. Wampler et al., Phys. Scr. T170 (2017) 014041

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