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Time-Dependent Plasma Surface Interaction Modeling to Address Dynamic Recycling in a Tungsten Divertor

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Integrated modeling of plasma-surface interactions (PSI) provides a comprehensive and self-consistent description, moving the field closer to developing predictive and design capabilities for plasma facing components. This technique, using descriptions for the scrape-off-layer plasma provided by SOLPS, the sheath by hPIC, ion-surface interactions by F-TRIDYN and the sub-surface by Xolotl, has been successfully applied to interpret and predict steady-state PSI experiments in current and future tokamaks [1–4]. Here we describe further developments in our workflow to incorporate time-dependence and two-way information flow, to model transient scenarios (e.g., ELMs). We predict the evolution of W samples pre-damaged by He and exposed to ELMy H-mode plasmas in the DIII-D DiMES [5]. This presentation will describe two simulations to predict dynamic recycling. In the 1st, we explore the effect of ELM frequency. Our simulations show that the plasma solution bifurcates, as the solution converges towards the intra-ELM equilibrium for short ELM cycles, and towards the inter-ELM for long ELM cycles. The plasma temperature increases with the inter-ELM duration, which leads to increases in impact energy (E_{in}) with the inter-ELM duration. For long ELM cycles, high impact energies and shallow impact angles (A_{in}) lead to reflection rates $\sim$1, which dominate D recycling. The high D recycling (rather than ELM cycling) in turn directly impacts the D content accumulated in the W samples. In the 2nd, we explore code-coupling frequency, optimize the initial SOLPS solution and transport parameters, implement E_{in} and A_{in} values calculated by hPIC2, and improve the heat transfer description [6] in Xolotl. These simulations predict particle fluxes increase and heat fluxes decrease by 10-20% with the coupling timestep. A less shallow impact angle leads to smaller reflection rates and significant D implantation. The higher fraction of the implanted flux (and deeper), in particular during ELMs, increases the accumulated D content in the W near-surface region. Future expansion of the workflow includes coupling hPIC2 and GITR to ensure accurate prediction of Ein and Ain, and W impurity transport.

References
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