Self-consistent simulation of edge plasma transport with lithium sources*

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A self-consistent plasma-facing surfaces (PFC) model is essential for understanding lithium (Li) and plasma interactions and sourcing Li into the main plasma based on local plasma conditions and surface temperature. In this work, a self-consistent coupling has been developed between the plasma boundary transport code, UEDGE, and a separate wall code modeling heat transport in the material walls and Li flux off the wall.

The coupled model is currently applied to NSTX as a test bed. NSTX-U is a spherical tokamak designed to deliver significant heat flux to the divertor target plates, facilitating the study of Li divertor physics. The developed model will be utilized to explore the operational window of the NSTX-U Li divertor, particularly focusing on core contamination due to fuel dilution and radiation.

In the coupled model, Li fluxes from PFC, including contributions from physical sputtering (D^+ on Li), ad-atom processes, and evaporation, are determined in the wall code based on the calculated surface temperature (T_{surf}) and the incident main ion flux. These Li fluxes enter the boundary plasma in UEDGE as Li neutral atoms originating from the divertor plates, and UEDGE computes plasma and neutral transport, providing the surface heat flux with account for Li evaporation heat as a boundary condition to the wall code.

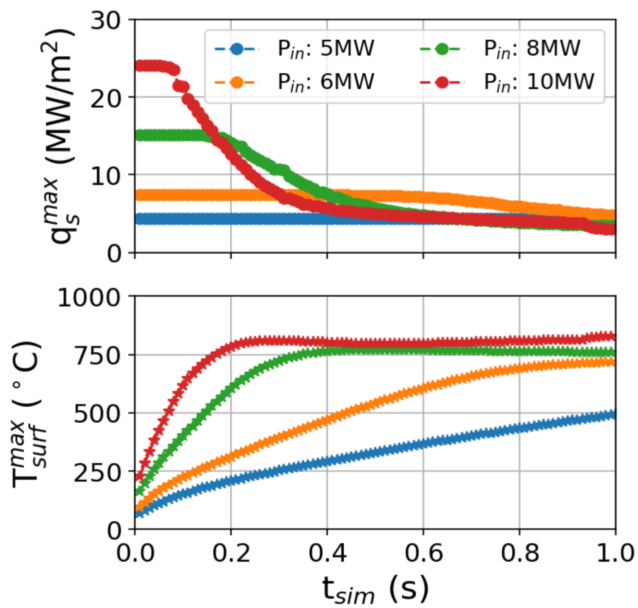

Fig. 1 Time evolution of peak surface temperature and heat flux as a function of the input power from the core. Vapor shielding limits T_{surf} under ~800°C despite increased heating power.

In these simulations, the input heating power is varied over a wide range to assess the sensitivity of Li erosion to the incident heat flux which is 5-25 MW/m^2 at the peak (Fig. 1, top). Power losses due to Li radiation cooling and the evaporative cooling which provides a vapor shielding effect [1], limiting the heat flux to the surface and maintaining constant Li surface temperature under 800°C even as the power from the core increases (Fig 1, bottom). Li radiation increases significantly when T_{surf} exceeds 500°C due to enhanced evaporation, resulting in reduced plasma heat flux and providing a vapor shielding effect. Li sourcing leads to localized radiation near the divertor surfaces, with higher surface temperatures (>600°C) leading to larger Li concentration near the separatrix.

[1] G Federici et al, Plasma Phys. Control. Fusion **45**, 1523 (2003).

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