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Inter vs. Intra-ELM Tungsten Erosion and Transport from the Divertor in DIII-D High-Performance H-mode Discharges

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Measured intra-ELM (during ELMs) tungsten erosion profiles in the DIII-D divertor, acquired via W-I spectroscopy with high temporal and spatial resolution, are consistent with OEDGE+SDTrim.SP modeling including measured ion saturation currents and ion impact energies. If pedestal temperature rather than divertor conditions are used as input, quantitative agreement is observed, for the first time, between the Fundamenski-Moulton 'free-streaming' (FMFS) model predictions of how W source scales with ELM deposited energy density when broadening of the divertor heat flux footprint and enhanced target electron densities (e.g., via increased neutral recycling) are taken into account. Consistency is observed between this new FMFS-SDTrim.SP model and experimental measurements of intra-ELM W sourcing across a range of ELM frequencies/sizes, except for ELMs with very low energy density. An interpretive model for the time evolution of the W physical sputtering rate during ELMs was also developed including impurity and main ion sputtering. This model reveals that both D and C contribute substantially to W sourcing during ELMs in the DIII-D divertor because the average ion impact energy increases from below to substantially above the energy threshold for D→W sputtering. The measured W sputtering profiles are well matched to this model with a 2% C^{2+} fraction, a factor of 2 higher than in the inter-ELM (between ELMs) phase. This work represents unique progress towards a predictive model to link pedestal conditions to the ELM-induced divertor W impurity source. Such models can be utilized in ITER and beyond to develop and optimize mitigation strategies for minimizing high-Z accumulation in the core.

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