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Theoretical analysis and experimental validation in DIII-D of predictive modeling for tungsten erosion and redeposition in tokamak divertors

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Fundamental mechanisms governing the prompt redeposition of tungsten impurities sputtered in tokamak divertors have been identified and analyzed to enable quantitative estimations and in-situ monitoring of the net erosion and lifetime of tungsten divertor plasma-facing components (PFCs) in ITER. In tokamak divertors, the width of the electric sheath is of the order of the main ion Larmor radius, and a vast majority of sputtered tungsten impurities are ionized within the sheath region in high-density attached divertor plasma conditions. Tungsten prompt redeposition is then mainly governed by the ratio of the characteristic ionization mean-free path of neutral tungsten over the width of the sheath, and a new scaling law for tungsten prompt redeposition in tokamak divertor was derived. It is also shown that in-situ monitoring of the prompt redeposition of tungsten impurities in divertors requires the measurement of photon emissions associated with the ionization of tungsten impurities in charge states $Z > 2^+$, typically, and for divertor plasma conditions expected in the far-SOL of the ITER divertor. Besides, S/XB coefficients (number of ionization events per photon) for tungsten impurities are significantly modified in high-density divertor plasma conditions because of the decrease of the electron density in the sheath region where sputtered tungsten impurities are ionized and because of the transient populations of metastable states of tungsten atoms. Finally, various experiments conducted at DIII-D to benchmark predictive models of tungsten prompt redeposition and net erosion in divertors are presented.

Primary author: GUTERL, Jerome (General Atomics, USA)

Presenter: GUTERL, Jerome (General Atomics, USA)

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