Advanced modelling of DIII-D tungsten divertor probe experiments for analysis of plasma ELM and non-ELM effects on sputter erosion, transport, and redeposition

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Understanding the processes involved in high-Z plasma surface interactions is a fundamental goal for the DIII-D tokamak Divertor Material Evaluation System (DiMES). Accordingly, we analyze a series of experiments \cite{1} in which tungsten spots deposited on graphite DiMES samples were exposed to both L-mode plasmas and H-mode plasmas with edge localized modes (ELMs). The L-mode experiments used the “big spot” (15 mm dia.) and “small spots” (1 mm dia.) technique \cite{2-4} to assess W net and gross erosion, respectively. Tungsten erosion in the DIII-D experiments is found to be primarily due to physical sputtering by incident carbon ions in several different charge states and to self-sputtering from redepositing tungsten ions.

We compute the time-dependent sputter erosion and transport of the tungsten by the incident plasma using the REDEP/WBC 3-D, full-kinetic, sub-gyro orbit, impurity erosion/redeposition code package, coupled with DiMES-surface simulations from the ITMC-DYN dynamic surface mixing and sputter response code \cite{5}. We compute near-surface L-mode plasma profile inputs to WBC using the data-calibrated OEDGE plasma fluid code. Using the newly developed WBC/ITMC code package coupling, the change in tungsten sputtering yields and sputtered atom velocity distributions - due to the evolving carbon-containing and deuterium-containing tungsten surface - is self-consistently determined. Modeling also incorporates the detailed DIII-D oblique incidence magnetic sheath structure at the divertor and resulting ion impact angle distribution.

These simulations allow code comparisons to be made with post-exposure erosion data from the L-Mode exposed W spots by Sandia Laboratories ion beam analysis and with in-situ plasma W1 photon emission measurements \cite{1} for the ELMy exposures. We also compare present simulation results to those in \cite{4} for DiMES/tungsten with different plasma conditions.

\cite{1} T. Abrams et al., Nuclear Materials and Energy 17(2018)164
\cite{2} P.C. Stangeby et al., Journal of Nuclear Materials 438(2013)S309
\cite{3} D.L. Rudakov et al., Fusion Engineering and Design 124(2017)196
\cite{4} J.N. Brooks et al., Fusion Engineering and Design 94(2015)67
\cite{5} T. Sizyuk and A. Hassanein, Journal of Nuclear Materials 438(2013)S1109

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