Plasma-Material Interaction Modeling for High-Power Helicon Operation in the DIII-D Tokamak using STRIPE Framework

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The DIII-D tokamak has recently demonstrated high-power helicon wave operation for the first time in any tokamak, utilizing a traveling-wave antenna to couple about 360kW RF power (at 476 MHz) into L-mode plasmas[1]. While RF power is essential for plasma heating and current drive, a major concern is enhanced plasma-material interactions (PMI) due to sheath rectification, which induces large RF-driven voltages on antenna structures, leading to significant material erosion. To investigate PMI at the helicon antenna, we employ the Simulated Transport of RF Impurity Production and Emission (STRIPE) framework[2], which integrates multiple computational tools with varying physics fidelity, including SOLPS, COMSOL, RustBCA, and GITR(m). Using DIII-D discharge #195196, STRIPE simulations examine impurity transport, erosion, and deposition at the helicon antenna and target surfaces, incorporating local plasma conditions to assess RF sheath-driven impurity generation. The simulations provide net erosion and (re)deposition profiles, while also accounting for self-sputtering effects that influence material lifetime. A parametric scan of plasma density and coupled helicon power reveals that erosion fluxes are strongly influenced by plasma density but only weakly affected by helicon power in DIII-D conditions. The STRIPE simulations predict that the DIII-D Helicon discharge # 195196 was operated in a density range that has low rectified sheath voltages and impurity sputtering in agreement with the low measured impurity radiation. These findings provide crucial insights into the effects of helicon waves on PMI, and this study further identifies favorable and potentially limiting helicon operational regimes for DIII-D and other tokamaks, offering guidance for optimizing RF heating and current drive while minimizing material erosion and impurity transport.

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1. Pinsker, R.I., et al., *First high-power helicon results from DIII-D.* Nuclear Fusion, 2024. **64**(12), 126058.
2. Kumar, A., et al., *Integrated modeling of RF-Induced Tungsten Erosion at ICRH Antenna Structures in the WEST Tokamak**, in *arXiv:2412.08748v1 [physics.plasm-ph] 11 Dec 2024; submitted to Nuclear Fusion*. 2025.