Simulation of first wall erosion and high-Z impurity transport in EAST tokamak Boundary

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Tungsten is a primary candidate for plasma-facing materials in tokamaks. ITER has decided to replace the first wall material from beryllium to tungsten, adopting a fully tungsten wall. However, tungsten is a high atomic number (Z = 74) element and is incompatible with the main plasma. The accumulation of tungsten impurities in the plasma core can influence the steady-state operation of fusion, making the control of tungsten impurity accumulation one of the key concerns in nuclear fusion research.

Existing studies mainly focus on tungsten impurities generated by the erosion of the divertor target [1, 2], as intense energy and particle fluxes are primarily deposited on the target plates, leading to strong plasma-wall interactions. However, the first wall accounts for more than 80% of the plasma-facing surface in a tokamak, moreover it is closer to the main plasma, making sputtered impurities more easily to transport across magnetic field and enter the core. Therefore, the contribution of the tungsten first wall to core tungsten impurities cannot be ignored. Preliminary simulations for ITER suggest that the total tungsten impurity source from first-wall erosion may significantly exceed that from the divertor target [3]; however, these models do not consider a self-consistent simulation of the first-wall plasma.

In this study, the extended-grid version of SOLPS-ITER [4] is coupled with the kinetic tungsten impurity transport code IMPEDGE [5] to simulate first-wall erosion and tungsten impurity transport in the EAST tokamak. The IMPEDGE code is upgraded to simulate realistic first-wall erosion and the transport of sputtered impurities, including those in the far scrape-off layer. Additionally, the wall erosion induced by high energy neutral particles from charge-exchange reactions as well as drift are added to the IMPEDGE model. This study investigates tungsten impurity generation and core accumulation behavior under different background plasma conditions by varying the neon injection rate. Particular emphasis is placed on comparing tungsten impurities from the divertor target and the first wall. The results indicate that first-wall erosion is primarily driven by high energy neutral particles produced through charge-exchange collisions and the influx of highly charged impurity ions. Furthermore, the study quantifies the contributions of both the divertor and the first wall to core tungsten impurity concentrations under different discharge conditions.

References

[1] X. Zhao, C. Sang* et al., Plasma Phys. Control. Fusion **62** (2020) 055015
[2] Y. Wang, C. Sang* et al., Nucl. Fusion **63** (2023) 096024
[3] K. Schmid and T. Wauters, Nucl. Mater. Energy **41** (2024) 101789
[4] W. Dekeyser et al., Nucl. Mater. Energy **27** (2021) 100999.
[5] Y. Wu, Q. Zhou, C. Sang et al., Nucl. Mater. Energy **33** (2022) 101297