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Active Control of Plasma Wall Interaction and Core Impurity toward High Performance Long Pulse Operation in EAST

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Effective control of PWI is one critical challenge for continuous operation of a tokamak for fusion energy. The good compatibility of the solutions to the boundary interface with the high-performance core solutions is a necessary condition for steady-state tokamak operation. Great efforts have been made to address the issue in the EAST superconducting tokamak, and a world record long pulse H-mode operation of 101.2 seconds with H_98=1.1 and a total power injection of 0.3 GJ has been successfully achieved in EAST with ITER-like top tungsten (W) divertor. The ITER-like W monoblock structure with steady-state power exhaust capability of 10 MWm^{-2} has been employed in EAST upper divertor since 2014 [1] and provides an infrastructure basis for developing high power steady-state scenario. Lower H-mode power threshold and better global plasma confinement can be achieved in upper single null configuration with reversed B_t direction. This could be related to the lower edge deuterium recycling and concurrently more stiffened edge n_e profile, demonstrating the important impact of divertor material on the plasma.

Tungsten as heavy impurity can degrade the confinement of core plasma due to strong radiation power loss by highly ionized W atoms. Various control capabilities on tungsten sources and transport have been developed and investigated in EAST. Main chamber lithium evaporation can effectively suppress W source by reducing the low Z impurity contents and forming mixture deposition layer on wall surface [2, 3]. Real-time Li aerosol injection provides a more efficient method for mitigating divertor W sputtering, reducing edge D recycling as well as for edge localized mode (ELM) control. ELM mitigation and 3D effects supported by lower hybrid wave (LHW) heating and resonant magnetic perturbation can reduce transient peak heat flux and broaden the plasma wetted area on divertor target [4-7], thereby mitigating the impurity source. Increasing ELM frequency and divertor collisionality with increasing divertor radiation benefits pedestal flushing and divertor screening [8]. LHW heating can effectively suppress the impurity accumulation in core plasma in L-mode discharges [9]. Strong ~25 kHz edge coherent modes (ECM) is observed in LHW heated high-enhanced-recycling (HER) H-mode discharges, which is believed to result in lower impurity confinement time and higher energy confinement time [9]. Central electron heating employing electron cyclotron resonant heating can effectively repulse impurity ions from plasma center by controlling central density and temperature profiles, and consequently avoid central high-Z impurity accumulation.

The control of divertor detachment in H-mode with impurity seeding using divertor probe feedback has been developed. The compatibility of small-ELM regime with radiative divertor has also been successfully demonstrated in EAST. These provide well-controlled edge conditions and contribute to the development of integrated PWI control scheme toward high performance long pulse operation in EAST with high-Z walls.

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