PROGRESS OF CORE-EDGE INTEGRATED TUNGSTEN TRANSPORT STUDY IN EAST WITH ITER-LIKE TUNGSTEN DIVERTORS USING ADVANCED IMPURITY DIAGNOSTICS

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Experimental Advanced Superconducting Tokamak (EAST) has been equipped with upper and lower tungsten (W) divertors since 2014 and 2021, respectively. Impact on the plasma performance in its steady-state operation must be studied in detail as the highest priority issue in EAST in addition to the study of W transport. For this purpose, fast-time-response and space-resolved extreme ultraviolet (EUV) spectrometer systems [1-3] have been developed for studies on time behavior and spatial distribution of W ions. Meanwhile, an integrated modelling for the simulation study on core W transport has been also developed under OMFIT framework [4]. The W transport characteristics at plasma core in hybrid [5] and fully non-inductive [6] discharge scenarios are explored by combining simulation and experimental studies. As a result, on-axis ECRH [6], 4.6GHz LHW [7] and ICRF [8] heating has proved to be effective to control the core W ions by enhancing the radial transport. On the other hand, up/down poloidal asymmetry was observed for W ions in EAST for the first time [9]. Toroidal rotation was found to play an essential role in enhancing the asymmetry. A strong asymmetric distribution was also found for ions existing in the peripheral region.

Based on the simulation study, turbulent W transport is predicted to be dominant over the neoclassical transport in plasma core region of conventional H-mode discharges in both ITER [10] and CFEDR [11] next-generation tokamaks. A more important point, however, is the control of W ions in the edge pedestal region. Unfortunately, the study on pedestal tungsten transport remained insufficient due to a lack of the line observation for weakly and moderately ionized W ions and the absence of transport modelling for the pedestal region. Recently, weekly and moderately ionized W^{4+}-W^{20+} ions existing in the SOL-pedestal-edge regions including other metallic impurity ions have been observed and identified [12,13] in the EAST plasma based on the advanced impurity diagnostic system. Benefiting from the observation, a diagnostic gap between divertor W source and core W behavior, i.e., a spectral gap between W atom and highly ionized W ions of W^{24+}-W^{45+}, can be adequately filled. A collision-radiative (CR) model has been built for such weekly ionized W ions, e.g. W^{5+}, to calculate the photon ionization event (S/XB) for W influx evaluation [14]. The modelling was also utilized to study an effect of 3D RMP field on the edge impurity screening in EAST [15]. Currently, a universal approach to calculation on the photon emissivity coefficient (PEC) of high-Z impurity ions with multiple ionization stages is being under development, which will significantly contribute to the enhancement of the ADAS database. Thus, a quantitative analysis becomes possible on the influx and density of W ions at SOL-pedestal-edge plasma regions.

Very recently, core-edge integrated W behavior study was initiated for H-mode discharges under distinct ELM activity regime, particularly by using W burst events. Line emissions from W^{4+} - W^{8+} are used to study W behaviors at SOL, e.g. W^{4+} at 434.3 Å, W^{5+} at 382.1 and 394.1 Å, W^{6+} at 216.219 and 261.387 Å, W^{7+}-W^{8+} at ~200Å. Line emissions from W^{13+} at ~250Å and W^{14+}- W^{16+} ions at ~300 Å are also used for the W behaviour study at pedestal region. The tungsten unresolved transition array (W-UTA) at 45-70 Å from W^{24+}- W^{45+} ions and at ~60 Å and 120-130 Å from W^{40+}-W^{45+} ions are used for the W behavior study at edge and core regions. Figure.1 shows a typical time evolution of line intensities from W^{6+}-W^{8+}, W^{14+}-W^{20+}, W^{23+} and W^{26+} and W^{40+} ions during W bursts in the H-mode phase with small ELMs. The core-edge integrated W transport analysis is being performed based on the simultaneously observed spatiotemporal spectra on multiple W ions. Tungsten transport coefficients are then determined by comparison between observed and reconstructed time traces of the W line intensities using STRAHL transport code and PECs calculated from the CR model mentioned above.

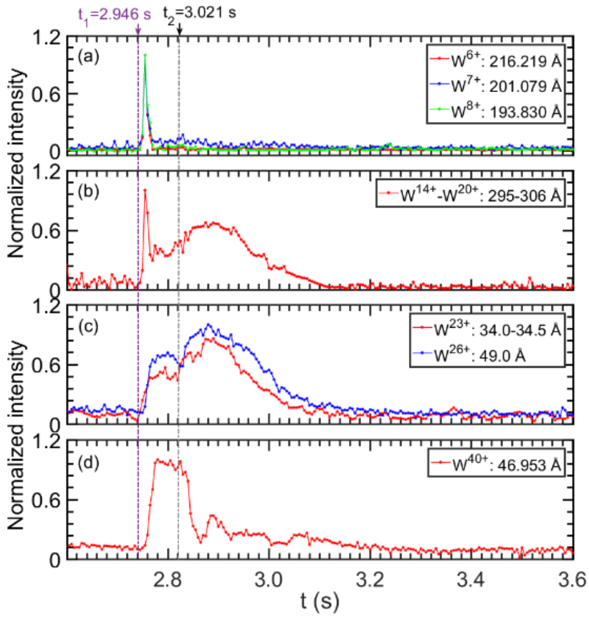

Fig.1 Time behaviors of line intensities of (a) W^{6+}-W^{8+}, (b) W-UTA at 295-306Å composed of W^{14+}-W^{20+}, (c) W^{23+} and W^{26+} and (d) W^{40+} during two timings of W bursts in H-mode phase with small ELMs. Those lines are used to study W influx and transport at plasma edge and core regions. Two dashed lines indicate the start of two W bursts at t_1=2.946s and t_2=3.021s. Note that weekly ionized W ions of W^{6+}-W^{8+} was observed only at the first W burst, and the intensity of W^{40+} drastically drops after the second W burst due to a sudden temperature decrease from 2.6keV to ~1.5keV.

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