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Recent progress on high-Z impurity diagnostics development and tungsten transport study on EAST Tokamak

ZHANG Ling[1], CHENG Yunxin[1], HU Ailan[1], MORITA Shigeru[2], ZHANG Wenmin[3,1], ZHANG Fengling[3,1], MITNIK Darío[4,1], LI Zhengwei[5,1], ZHOU Chenxi[1], ZHOU Zhen[3,1], CAO Yiming[5,1], MA Jiuyang[3,1], XU Zhehao[5,1], XU Lang[3,1], LIU Haiqing[1]

[1] Institute of Plasma Physics, Chinese Academy of Sciences
[2] National Institute for Fusion Science, Toki, Japan
[3] University of Science and Technology of China, Hefei, China
[4] Instituto de Astronomía y Física del Espacio, Argentina
[5] Anhui University, Hefei, China
E-mail (speaker): zhangling@ipp.ac.cn

Impurities play an essential role in maintaining high-performance plasmas in magnetic confinement fusion research because the radiation power loss and bulk ion dilution caused by the impurity ions quickly degrade the plasma performance. It is well known that radiation loss quickly increases with the atomic number of the impurity element. In International Thermonuclear Experimental Reactor (ITER), on the other hand, tungsten is used as the divertor material instead of carbon. Upper and lower graphite divertors in Experimental Advanced Superconducting Tokamak (EAST) were replaced by tungsten divertors in 2014 and 2021, respectively, to improve plasma performance in long pulse discharges and accumulate knowledge on the tungsten divertor operation. Studies on the tungsten behavior in edge and core plasmas are crucial for enhancing plasma performance. For this purpose, a complete set of tungsten spectroscopy diagnostic systems has been developed and installed on EAST tokamak, which consists of a visible (VIS) spectroscopy system, fast-time-response, and space-resolved extreme ultraviolet (EUV) spectroscopy systems.

Fast-time-response EUV spectroscopy system includes four grazing-incidence flat-field spectrometers developed on EAST since 2014 [1][2]. One is working at 5-138 Å, and the other three are working at 20-500 Å. EUV spectra with high spectral resolution at the full range of 5-500 Å could be observed simultaneously in each discharge at a sampling rate of 5 ms/frame. Hundreds of emission lines from tungsten ions W^{4+}-W^{45+} have been carefully identified from the EUV spectra as a fundamental work [3]. Moreover, a database of EUV lines from multiple impurity elements in fusion plasma has been preliminarily built [4][5]. Space-resolved EUV spectroscopy system also includes four spectrometers, which have been installed successively since 2017. Two of them working at 5-138 Å provide the tungsten line intensity profiles in $\rho \leq 0.3$ with 15-50 ms/frame, and the other two working at 30-520 Å provide that in $\rho \leq 0.7$ with 50-200 ms/frame [6][7]. Quantitative analysis of tungsten concentration and impurity ion density profiles are then performed using the EUV spectroscopy for the tungsten transport study [8]. Additionally, since 2021 VIS spectroscopy system with two optics and spectrometers has been developed successfully [9]. One is designed for an adjustable 2D profile measurement of tungsten sputtering in the upper divertor. The other is for the total radial profile measurement of Zeff and M1 transition from tungsten ions of W^{8+}-W^{28+}.

Benefiting from the high-performance impurity diagnostics studies on tungsten transport and its control have been widely carried out in EAST combined with experiment and simulation, e. g. the effect of electron cyclotron resonance heating (ECRH) and lower hybrid wave (LHW) heating on tungsten transport, impurity transport behavior at plasma edge with application of resonance magnetic perturbation (RMP) coils, and the effect of plasma rotation on up-down asymmetry distribution of tungsten ions. The preliminary results will be introduced in the talk.

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