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Experimental observation and modelling of high-Z impurity transport by tungsten powder injection in KSTAR plasmas

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In fusion plasmas with electron temperature of several keV, most of the tungsten (W) particles are in W27+ to W45+ ionic states, which emit line radiations of a few nm wavelength in the EUV range. Thus, a compact (63x44x18 cm3) advanced EUV spectrometer system (CAES) was recently developed [2] to simultaneously measure spectrally-resolved tungsten emission and spatially-resolved W density profile. Since the 2016 KSTAR campaign, a few mg of W powder of 12 μm typical size was injected to the plasma by a portable compact (60x30 mm2) gun-type particle injector [1] which can inject any kind of metal powder. During the experiments, spatiotemporally varying W spectra were successfully obtained by CAES with 2.7 cm and 67 ms of spatial and time resolutions. In conjunction with these experimental setups, a spectral model for high-Z impurity transport has been developed based on coronal approximation. The Flexible Atomic Code (FAC) is used to calculate the PEC of W10+ to W48+. The modelled line emissions are compared with the measured data in order to find proper diffusion coefficients and convection velocities from the radial continuity equation. In addition, the radiation power loss relation and the force balance equation with a centrifugal force effect are included to find the two-dimensional global density profile of high-Z impurities and a relation between the toroidal rotation speed and poloidal asymmetry. These schemes are possible by using the infrared imaging video bolometer (IRVB) diagnostics in KSTAR, through which we observed a poloidally asymmetric distribution of tungsten emission due to the centrifugal force effect in the past KSTAR campaigns. Code validations were performed by comparing with the results from SANCO [3], showing a good agreement within 10% error of the intensity of Ar15+ 35.3 nm line emission. It is also clearly seen that more spectral lines appear in the modelled structure than in the measured spectrum, which is possibly an indication that a refined description of the W atomic structure must be included in our calculation.

References:

[1] H. Y. Lee et al., Rev. Sci. Instrum. 85, 11D862 (2014)
[2] I. Song et al., Rev. Sci. Instrum. 88, 093509 (2017)
[3] J. Hong et al., Nucl. Fusion 57, 036028 (2017)

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