§5. Spectroscopic Studies on Mechanism of Tungsten Accumulation

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Tungsten is one of the candidates for plasma facing components in future fusion devices such as ITER and DEMO. However, because of its high Z number, tungsten is not fully ionized in plasmas, and the intense line-radiation dissipates plasma energy, leading to plasma collapses. Hence it is of significance to avoid accumulation of tungsten ions in a core plasma. For this purpose, it is required to establish a method to determine tungsten ion density in the plasma quantitatively. Spectroscopic measurement of tungsten spectra has been widely used and analysis with an atomic code has been extensively performed. In the present work, a tungsten spectrum measured in an LHD plasma at a center electron temperature of 3 keV, shown in Fig. 1 (upper), was analyzed with an atomic code, named FAC [1].

Spectrum calculation with FAC was performed for W^{14+} - W^{71+}. In the calculation, for instance, for W^{27+} (Ag-like tungsten ion), the following electron configurations besides the ground state ($4d^{10}$ 4f) were considered:

$4d^9 + 4f^2$

$4d^{10}$ + 5s, 5p, 5d, 5f, 5g, 6s

$4d^9$ 4f + 5s, 5p

In calculation for W^{14+} - W^{24+}, only a few Δn=1 transitions between n=4 and n=5 level such as those between $4d^9$ 4f 5s and $4d^9$ $4f^2$, were considered in addition to Δn=0 (n=4) transitions. This is because inclusion of all Δn=1 and Δn=0 (n=5) transitions increased huge computational time. Then, a collisional-radiative model, which included the processes of (de-) excitation between these levels and radiative transition from these levels, was used to calculate spectra of each tungsten ion. As shown in Fig. 1 (lower), many spectral lines due to transitions between 4p - 4d and 4d - 4f were distributed between 4.5 nm and 6 nm. These spectra were summed up with ratios shown in the left of Fig. 1 (lower), and then the synthesized spectrum was obtained. In order to determine the weight, comparison of the measured and the synthesized spectrum and adjustment of the weight, were repeated. As a result of this procedure, good agreement between the measured and the synthesized spectrum was obtained as shown in Fig. 1 (upper). Note that it is the first time in the series of the present work that quasi-continuum between 5 and 6 nm was reproduced. As shown in the left of Fig. 1 (lower), the determined weight was a sum of broad distribution for W^{14+} ~ W^{45+} and peaked distribution around W^{43+}. This suggests that the radial charge-state distribution along the viewing chord is approximately equal and that highly charged tungsten ions accumulate at the plasma core. The population of the highly charged tungsten ions in the peaked distribution is not so large compared to that in the broad distribution, while the population of the highly charge tungsten ions was significantly higher in JT-60U [2]. Therefore, it is probable that the tungsten accumulation trend in LHD is weaker compared to that in JT-60U.

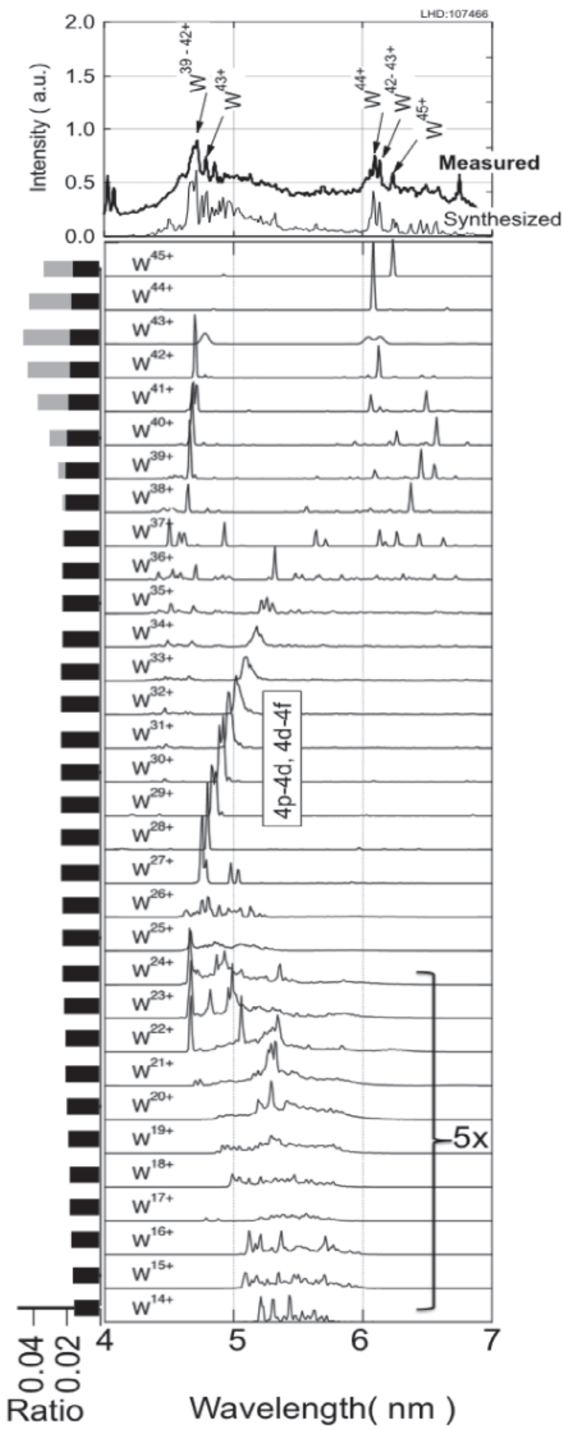

Fig. 1. (Upper) measured and synthesized spectrum, (lower) calculated W ion spectra, and (left of the lower figure) charge-state distribution of the synthesized spectrum.

1) Gu M.F., The Astrophysical Journal **582** (2003) 1241.

2) Nakano, T. et al,: J. Nucl. Mater. **415** (2011) S327-S333.