§8. Collisional-radiative Models of W Ions for Plasma Diagnostics

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Tungsten is planned to be used as plasma facing material for a divertor plate of ITER and fusion reactors because of low erosion yield and low deuterium retention. However, once tungsten is sputtered into plasma, it is transferred to a core plasma region and causes serious radiation loss to cool the plasma. To keep hot plasma for fusion reaction, we need to know how tungsten is transfer into plasma, how much radiation loss is caused by tungsten, and how to control tungsten transfer in a reactor. For this purpose, we first need a spectral model to analyze spectra to obtain tungsten ion densities and radiation loss. A collisional-radiative (CR) model is widely used to estimate spectral line intensities with given electron density and temperature. The CR model solves rate equations of excited states with steady-state assumption, and the model includes electron collision processes between excited states.

We have been constructing two kinds of CR models for W ions. One is to calculate ion abundances[1] and the other is to calculate spectral lines. We use the HULLAC code[2] to calculate atomic data for the CR models.

Extreme ultraviolet (EUV) spectra measured in LHD plasma for different central electron temperature, 0.7keV and 1.5keV are shown in Fig. 1(b) and (e). There several peaks are observed and their charge states are identified as indicated in the figure by comparison with similar spectra measured in CoBIT[3] (Figs.1 (a) and (d)) and spectra calculated with the CR model (Figs. 1 (c) and (f)). Ion abundances are determined to fit the measured LHD spectra with the calculated spectra as shown in Fig. 2. For comparison ion abundances calculated with assumption of ionization equilibrium[1] are also shown in Fig. 2 and we found the obtained abundance distributions tend to resemble to the equilibrium abundance distributions with lower electron temperature than the central temperature, i.e. measured distribution with Te=700eV resembles to equilibrium distribution with 378eV and the another case of Te=1.5keV resembles to the 946eV equilibrium distribution. These tendencies imply two possibilities that the ionization delays behind the ionization equilibrium or those tungsten ions exist not in the center but at lower temperature region in the LHD plasma. We need to examine the special distribution of W ions in LHD plasma for further investigation.

1) Sasaki, A and Murakami, I., J. Phys. B **46**, 175701 (2013).
2) Bar-Shalon, A. et al., J. Quant. Spect. Rad. Transf. **71**, 179 (2001).
3) Sakaue, H. A. et al., AIP Conf. Proc. **1438**, 91 (2012).

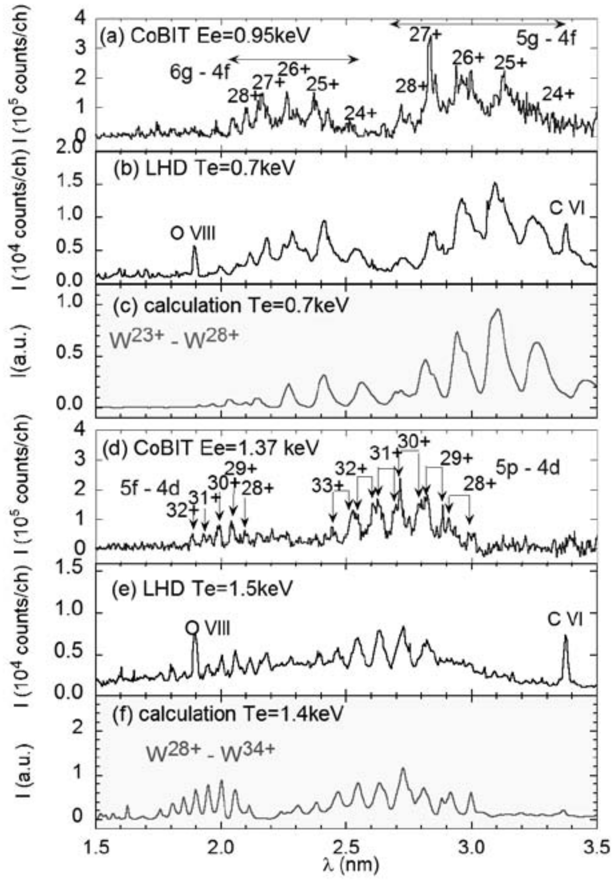

Fig. 1 EUV spectra of tungsten ions; (a, d) CoBIT with two electron beam energies E_e, (b, e) LHD with different electron temperature T_e, and model calculations for (c) W^{23+} - W^{28+} and (f) W^{28+} - W^{34+} ions. Wavelengths in calculation at (c) are shifted by -0.15 nm to fit the position to measurements.

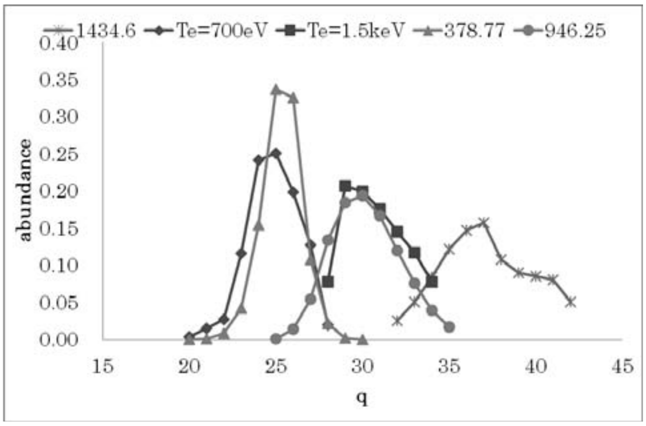

Fig. 2. Charge state distributions of W ions obtained to fit with LHD spectra in Figs. 1(b) (700eV; ◆) and (e) (1.5keV; ■) with distributions calculated with given electron temperature for ionization equilibrium plasma (× for 1434eV, ▲ for 378eV, and ● for 946eV).