§9. Spectral Line Model of W Ions for Plasma Diagnostics

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Tungsten is the most possible candidate for plasma facing material for a divertor plate or the first wall of a fusion device because of low erosion yield and low deuterium retention. However, once tungsten is sputtered into plasma and is transferred to a core plasma region, it would cause serious radiation loss to cool the plasma. The central concentration in the ITER must be less than several 10^{-5}. In order to estimate concentration of tungsten in plasmas, spectroscopic measurement is an important tool and a spectral model is required to analyze spectra to obtain ion densities from spectral line intensities. 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, which can treat electron density effect.

We have been constructing CR models of W ions. We use the HULLAC code[1] to calculate atomic data for the CR model. Here recombination processes are not included in the CR model, since recombination processes are less important for most of laboratory plasma condition. So far we have CR models for tungsten ions from W^{20+} up to W^{43+} ions, including open 4f shell ions ($W^{20+} \sim W^{27+}$), closed and open 4d shell ions ($W^{28+} \sim W^{37+}$), and closed and open 4p shell ions ($W^{38+} \sim W^{43+}$). For each CR model, excited states up to principal quantum number n =6 are considered.

Spectral feature is different from ions with different atomic structure. For example, at the extreme ultraviolet (EUV) wavelength region from 1.5nm to 4.5nm, open 4f shell ions show mainly 6g – 4f and 5g – 4f transitions which consistent of many weak lines. For open 4d shell ions there are many transitions appeared, such as 5p - 4d, 5g – 4f, 5f – 4d, 5d – 4f, and 6f – 4d transitions (Fig.1). Such characteristic spectral features are excellently agreed with spectra measured by the compact electron beam ion trap device (CoBIT)[2].

For EUV wavelength region from 4nm to 7nm, an unresolved transition array (UTA) is measured for plasma with electron temperature ~1keV in LHD or ASDEX Upgrade[3]. We need to reconstruct such UTA feature in the EUV spectrum. Spectral characteristics of each ion with Maxwellian distribution for electron velocity are examined. Figure 2 shows example of spectra for electron temperature 1keV and electron density 10^{13}cm^{-3}. UTA features by 4f-4d, 5d-4f, and 4d-4p transitions in open 4f shell and 4d shell ions are found. Closed shell ions do not show UTA spectra. Such characteristics of these spectra will be examined in more detail and we will try to reconstruct measured UTA spectra.

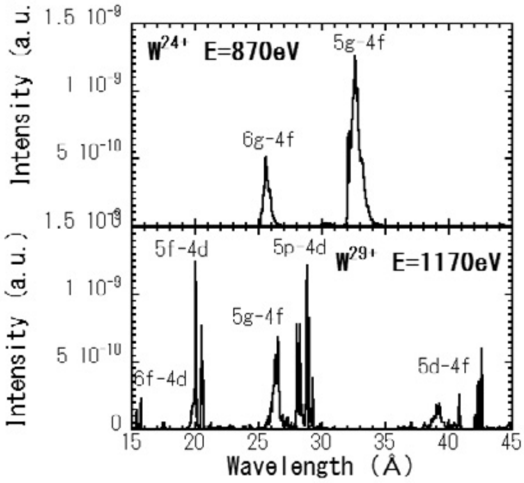

Fig. 1. EUV spectra calculated with a CR model for W^{24+} with mono electron beam energy 870eV and W^{39+} with mono electron beam energy 1170eV to compare with CoBIT experiments. Electron density is assumed as 10^{10}cm^{-3} for both cases.

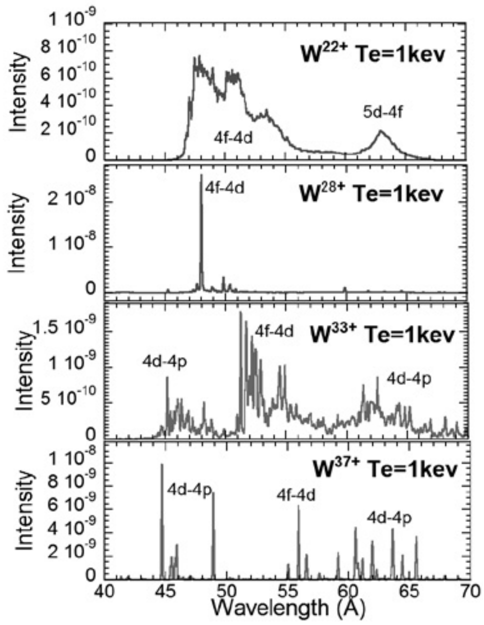

Fig. 2. EUV spectra calculated with CR models for W^{22+}, W^{28+}, W^{33+} and W^{37+} ions with electron temperture 1keV and electron density 10^{13}cm^{-3}.

1) Bar-Shalon, A. et al., J. Quant. Spect. Rad. Transf. 71, 179 (2001).

2) Sakaue, H. A. et al., AIP Conf. Proc. Vol. 1438, (AIP), in press (2012).

3) Pϋtterich, T. et al., Plasma Phys. Control. Fusion 50, 085016 (2008).