§11. 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 the W is introduced into plasma and its concentration in a core plasma region would cause serious radiation loss to cool the plasma. The central concentration in the ITER is said to be less than several 10^{-5}. In order to measure how much W is concentrated 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 in steady-state assumption, and the model includes electron collision processes between excited states can treat electron density effect. A coronal model, on the other hand, is very simple and easy to construct, since it requires only electron impact excitation from the ground state and radiative decays from excited states. This model can be applied only for low density plasmas.

We have been constructing CR models of W ions. The CR model needs many atomic data, such as transition probabilities, electron-impact excitation rate coefficients, electron-impact ionization rate coefficients, and recombination rate coefficients. 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, except for a recombining plasma.

Because atomic number of W is 74, W has 74 ionic states and we have tried to construct CR models for W^{26+}, W^{27+}, W^{28+}, W^{29+}, W^{35+}, W^{36+}, and W^{37+} at the moment. Figure 1 shows examples of W^{35+} spectra for electron temperature 1keV and electron density 10^{10}cm^{-3} (a), $3x10^{13}$cm^{-3} (b), and 10^{20}cm^{-3} (c), to model EBIT spectrum, spectrum for fusion plasma, and spectrum for laser produced plasma. The density effect is clearly seen as difference. The spectral shape of high density case looks very similar to the gA (weighted transition probability) distribution. This means the plasma in thermal equilibrium. On the other hand, the low density case is close to a coronal model. The fusion plasma requires treating density effect properly with the CR model. We have measured EUV spectra from LHD plasma in which W TESPEL was injected. The W EUV spectra show a quasi-continuum like feature, called an unresolved-transition array (UTA) at 45 – 70 Å region. This feature cannot explain with spectrum of one ionic state, such as W^{35+}. We need to convolute spectra of wide ionic state range to explain the measured EUV spectra of LHD plasmas.

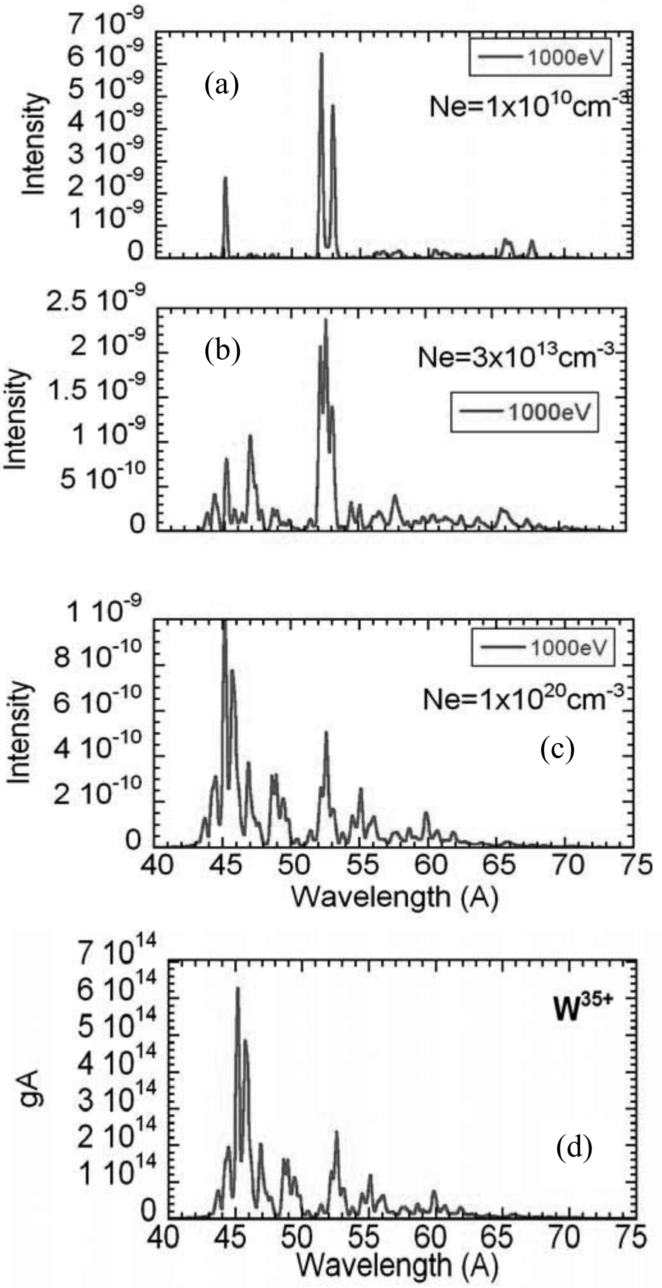

Figure 1. EUV spectra calculated with a collisional-radiative model for W^{35+} with electron temperature 1keV and electron density 10^{10}cm^{-3} (a), $3x10^{13}$cm^{-3} (b), and 10^{20}cm^{-3} (c). (d) shows weighted transition probability distribution for the same wavelength region for a comparison.

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