§86. Extreme Ultraviolet Spectra of W Ions Measured in LHD Plasmas

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Tungsten is planned to be used as plasma-facing material of divertor plates in the ITER and spectral data of W ions are needed for spectroscopic diagnostics to examine impurity transfer and concentration of W ions in fusion plasma. Even though many experimental and theoretical studies on W ion spectra have been carried out by many groups, W spectra are not fully understood, especially for plasmas with electron temperature around and less than ~1keV. If electron temperature is higher than 3keV, W ions are highly ionized and spectral feature becomes simpler with discrete lines. Extreme ultraviolet (EUV) spectra at wavelength region 4nm – 7nm for plasma with electron temperature around ~1keV have a characteristic feature, unresolved transition array (UTA) with double wide peaks, which are observed in LHD or ASDEX Upgrade[1)]. None of theoretical models succeeded to reproduce this UTA so far.

We have been constructing collisional-radiative (CR) models of W ions. CR models are widely used to estimate spectral line intensities with given electron density and temperature. A CR model solves rate equations of excited states in steady-state including electron collision processes between excited states. We use the HULLAC code[2)] to calculate atomic data for the CR model. Here recombination processes are not included in the CR model for spectral synthesis, since recombination processes are less important for most of laboratory plasma condition. Excited states up to principal quantum number n =6 are considered in the model. We also construct another CR model to calculate ion abundances in ionization equilibrium. Atomic data for the latter model are calculated with the HULLAC code in configuration mode, where fine structures are all bundled and only configurations are considered for atomic structure.

We measured EUV spectra by SOXMOS for LHD plasmas in which a tracer encapsulated pellet (TESPEL) with tungsten was injected. We changed heating condition with neutral beams and obtained various EUV spectra with different central electron temperature. Figure 1 shows temporal change of EUV spectra of W ions for λ 4nm-7nm range and the shape of UTA changes by time with different electron temperature profile.

Figure 2 shows synthesized spectra for W ions in ionization equilibrium with various electron temperatures. Measured spectra should be compared with sum of these synthesized spectra weighted with electron densities, ion densities, and path lengths of the spectral measurements. We will consider special distributions of electron density and temperature to synthesize more realistic spectra to compare with measurements.

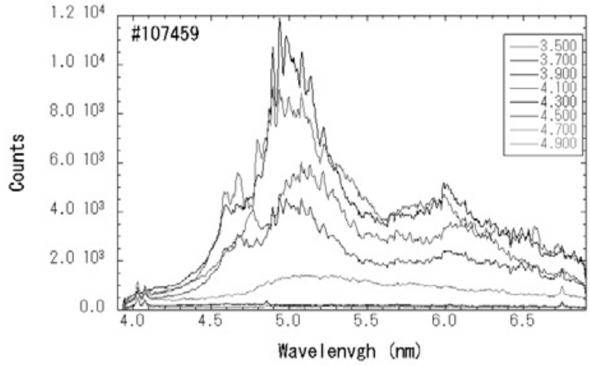

Fig. 1 EUV spectra measured in LHD plasmas. TESPLE was injected at t=3.8s. Central electron temperature changed from 2.5keV (t=3.9s) to 0.3keV (t=4.5s).

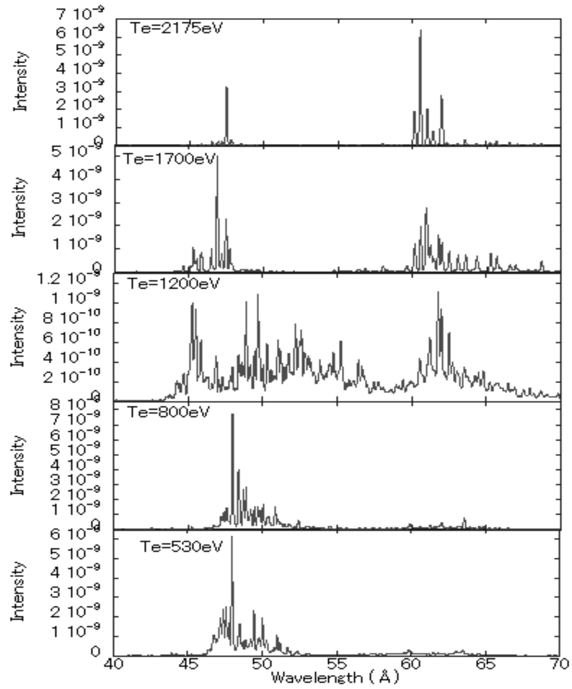

Fig. 2. EUV spectra calculated with CR models for electron temperature 530eV, 800eV, 1200eV, 1700eV and 2175eV from bottom to upper panels with electron density $10^{13}cm^{-3}$. Ionization equilibrium is assumed for ion abunndances.

1) Pütterich, T. et al., Plasma Phys. Control. Fusion **50**, 085016 (2008).
2) Bar-Shalon, A. et al., J. Quant. Spect. Rad. Transf. **71**, 179 (2001).