§11. Spectroscopy of Highly Charged Tungsten Ions with a Compact Electron Beam Ion Trap

Sakaue, H.A., Kato, D., Murakami, I.,
Yamamoto, N. (Chubu Univ.),
Nakamura, N. (Univ. of Electro-Commu.)

Tungsten will be used as material for the divertor plates in ITER because of higher sputtering threshold energy for light ion bombardment, the highest melting point among all the elements, and less tritium retention compared with carbon based materials. However, since extremely high particle- and heat-fluxes of the intermittent edge plasma transport (*e.g.* edge-localized-mode) in ITER would cause serious damages to such components, tungsten is considered to be one of the most abundant impurities in the ITER plasma. Emission lines of highly charged tungsten ions thus play an important role in the spectroscopic diagnostics of the ITER plasma, and consequently the spectroscopic data of tungsten ions have been studied at several facilities [1-3]. An electron beam ion trap is a useful device for the systematic spectroscopic studies of highly charged tungsten ions [4-7]. We have constructed a compact electron beam ion trap, called CoBIT [8-10], for spectroscopic studies of moderate charge state ions.

In this paper, we present extreme ultraviolet (EUV) spectra of highly charged tungsten ions (W XX ~ W XXXIV) in the wavelength range of 15~45 Å obtained with a compact electron beam ion trap. The electron energy dependence of spectra is investigated for electron energies from 540 to 1370 *eV*. Several tens of previously unreported lines are presented, and some of them are identified by comparing the wavelength with theoretical calculations. Figure 1(a) shows the EUV spectra at electron energies (E_e) between 540 and 1370 eV. Corrections for spectrometer response and detector efficiencies were applied to the spectra using catalog data. As seen in the figure, the overall EUV spectra show significant dependence on the electron energy. As the electron energy increases, the wavelength of strong emission lines shifts to shorter wavelength region.
The charge state of ions responsible for these lines can be identified from the appearance energy in a similar way to the previous study [10]. In fig. 1(b), the charge state dependence of calculated wavelengths is shown. The solid line, dashed line, dotted line and dashed two-dot line are calculated average wavelengths corresponding to the 6g-4f, 5f-4d, 5g-4f and 5p-4d transition manifolds, respectively. The wavelength was obtained by averaging the wavelengths of all transitions in the each manifold weighted by their line strengths which were calculated by an originally developed collisional-radiative model (CR-model) [11]. The atomic data used in the model were calculated by using the HULLAC code [12] in so-called configuration mode. In the configuration mode, fine-structure energy levels were not calculated, and a configuration averaged energy of a given configuration and a total angular momentum *J* was concerned. Thus, the multiplet term and configuration interaction were not considered in this calculation. From the comparison, some observed lines have been identified as the 6g-4f, 5f-4d, 5p-4d and 5g-4f transitions of $W^{20\text{-}35+}$.

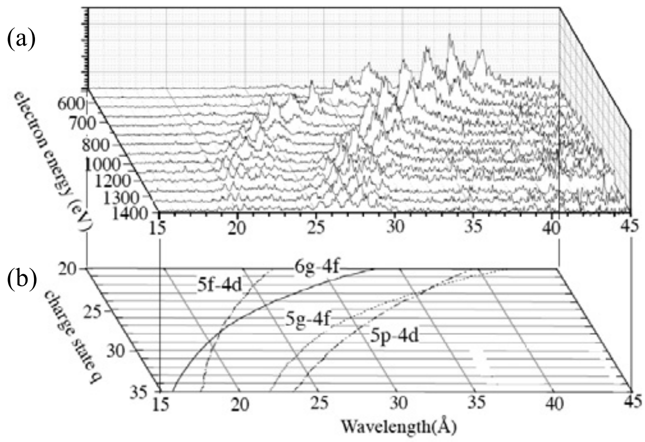

Figure 1 (a): Typical EUV spectra of highly charged tungsten ions obtained at electron energy *Ee* from 540 to 1370 eV in CoBIT. (b): The charge dependence of calculated wavelength.

1) Pütterich, T. *et al.* : *J. Phys.* B **38** (2005) 3071
2) Chowdhuri, M. B. *et al.*: *PFR* **2** (2007) S1060
3) Clementson, J. *et al.*: *J. Phys.* B **43** (2010) 144009
4) Clementson, J. *et al.*: *Phys. Rev.* A **81** (2010) 052509
5) Ralchenko, Y. *et al.* : *J. Phys.* B **40** (2007) 3861
6) Wu, S. *et al.* : *Can. J. Phys.* **86** (2008)125
7) Podpaly, Y. *et al.*: *Phys. Rev.* A **80** (2009) 052504
8) Nakamura, N. *et al.*: *Rev. Sci. Instrum.* **79** (2008) 063104
9) Sakaue, H. A. *et al.*: J. Phys.:Conf. Ser. **163** (2009) 012020
10) Sakaue, H. A. *et al.*: *AIP Conf. Proc.* (2012) 143891
11) Sakaue, H. A. *et al.*: *J. Appl. Phys.* **109** (2011) 073304
12) Bar-Shalon, A *et al.*: *J Quant. Spect. Rad. Transf.* **71** (2001) 179