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Spectroscopy of Highly Charged Tungsten Ions with the Electron Beam Ion Traps

タングステン多価イオンのEUV分光測定

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We present spectra of highly charged tungsten ions in the extreme ultra-violet (EUV) range observed by using the electron beam ion traps. The electron energy dependence of spectra is investigated for several electron energies from 490 to 1440 *eV*. The previously unreported lines are presented in the EUV range, and the electron energy dependence of them are measured.

Tungsten is a strong candidate for the material of the plasma-facing components, such as the first wall and divertor plates, in ITER because it has excellent physical properties, such as a low sputtering yield, a high melting point, a low tritium inventory, and so on. However, since high particle and heat fluxes 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 are strongly needed. To date, the spectroscopic studies of highly charged tungsten ions have been carried out by using high temperature (several *keV*) plasmas [1-2] and electron beam ion traps (EBITs) [1, 3-4] with relatively high electron energies (several to several tens *keV*). However, there is not yet enough data. In particular, the spectral data of moderate charge state tungsten ions (W^{10-30+}) are quite limited.

For the systematic spectroscopic studies of tungsten ions, we have been using two kinds of EBITs. One of them is the high-energy EBIT (Tokyo-EBIT) [5] constructed at the University of Electro-Communications (UEC), and another is the low-energy compact EBIT (CoBIT) [6,7] developed for spectroscopic studies of moderate charge state ions. Figure 1 (a) and (b) shown the present experimental setup for CoBIT and the Tokyo-EBIT.

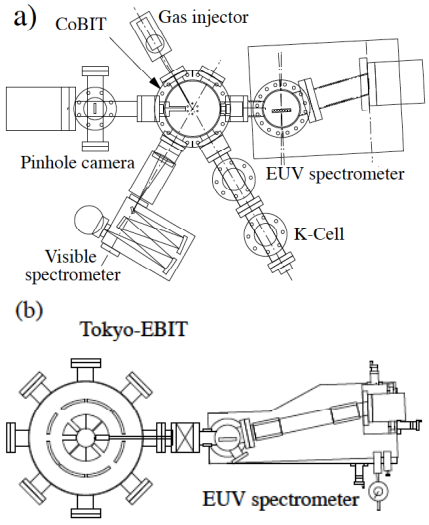

Fig.1 The experimental apparatuses of CoBIT and Tokyo-EBIT

We have constructed two CoBIT, and installed them at the UEC and National Institute for Fusion Science. The electron energy range of CoBIT and the Tokyo-EBIT is 0.1 - 2.5 *keV* and 2 - 200 *keV*, respectively, and the accessible charge states are about 10 – 40 and 40 – 74, respectively. The complementary use of them thus enables us to accumulate the atomic data of tungsten ions with a variety of charge states.

In this paper, we present extreme ultraviolet

(EUV) spectra obtained with the electron energy range 410 - 1440 *eV*. Grazing-incidence flat-field grating spectrometers especially designed for CoBIT was used for EUV emission in the 1 - 20 *nm* range. The previously unreported lines are presented, and some of them are identified by comparing the wavelengths with theoretical calculations.

Figure 2 shows EUV spectra obtained by using CoBIT with electron energies between 670 and 1210 *eV*. The corrections for the spectrometer response and the detector efficiencies were applied to the spectra shown in this figure. It is clear from the figure that the overall EUV spectra show significant dependence on the electron energy. The two peaks denoted by A and B are considered to be the emissions from the maximum charge state ion at each electron energy because they were not seen in the spectra with lower electron energies. For example, when the electron energy *Ee* increases from 800 to 870 *eV*, the maximum tungsten ion charge q produced in CoBIT is increased from 26+ to 27+. The emission lines of W XXVIII, which could not been seen at *Ee*= 800 *eV*, were observed at 21.5 *Å* (Peak A) and 28.3 *Å* (Peak B) at *Ee* =870 *eV*. As electron energy increases from 670 to 1210 *eV*, the charge states of the ions emitting these lines vary from W XXIV to W XXXI (W23+ ~ W30+).
In each spectrum, the emission lines from three or four charge states of highly charged tungsten ions are observed simultaneously. As the charge state increases, wavelengths of these emission lines (Peaks A and B) shift to the shorter wavelength-region.

The electron energy dependence of line intensity and its application to the plasma diagnostics are also discussed.

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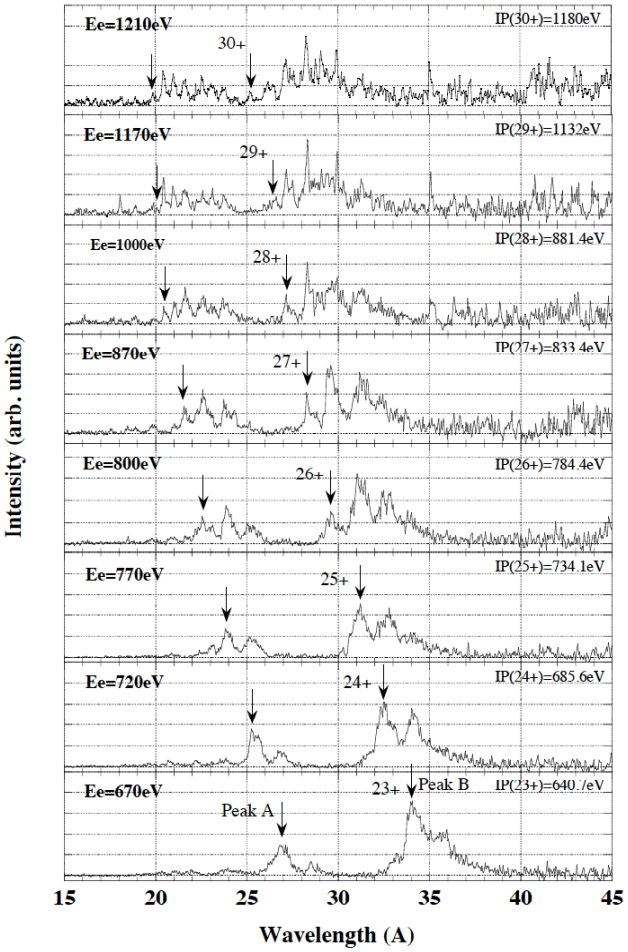

Fig.1 Typical EUV spectra of highly charged tungsten ions obtained at electron energy Ee from 670eV to 1210eV in CoBIT. IP(q+) is the qth ionization energy of tungsten ion.

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