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# Line emission spectra of tungsten impurity ions across visible, VUV, EUV, and X-ray wavelength ranges observed in a magnetically confined high-temperature plasma experiment

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Tungsten is a candidate material for plasma-facing components in ITER and future fusion reactors because of its high melting point and low sputtering yield. However, there is a concern that tungsten ions with a large atomic number of Z = 74 will cause large energy loss by radiation and ionization when the plasma is contaminated by the tungsten impurity. Therefore, it is important to understand and control tungsten impurity transport in high temperature plasmas for establishing reliable operation scenarios for fusion reactors.

Spectroscopic measurements of tungsten ions and atoms have been conducted in the Large Helical Device (LHD) using tungsten pellets to investigate the transport and to expand the database of tungsten line emissions. We have succeeded in a measurement of multiple charge states, from $W^{0}$ to $W^{46+}$ via visible, vacuum ultraviolet (VUV), extreme ultraviolet (EUV) and X-rays spectroscopy [1]. In LHD, the lines from the neutral atoms, $W^{0}$, and the magnetic dipole (M1) forbidden transition lines from$W^{26+}$ and $W^{27+}$, were observed using visible spectroscopy in the wavelength range of 3300–3900 Å. The lines from low charge states, $W^{2+}$–$W^{6+}$, and the several M1 lines from $W^{29+}$–$W^{39+}$ were observed in the VUV wavelength range of 500–1500 Å. In the EUV range of 5–500 Å, the lines from low charge states, $W^{4+}$–$W^{7+}$, medium charge states, $W^{24+}$–$W^{33+}$ in the structures of the unresolved transition array (UTA), and high charge states, $W^{41+}$–$W^{46+}$, were observed. $W^{46+}$ lines were also observed with high wavelength dispersion in the X-ray wavelength range of 3.87-3.90 Å.

On the other hand, a problem of the lack of line spectral data for a range of $W^{10+}$ to $W^{20+}$ has not been solved. These ions in low charge states are considered to be distributed in the edge plasma that connects the plasma-facing components and the core plasma in fusion reactors. Since impurity transport in the edge plasma greatly affects the characteristics of the core plasma, establishment of measurements for tungsten ions in low charge states is required. In order to observe these low- charged ions at LHD, we searched for spectra during the time period of a discharge when the central electron temperature is from 0 to about 0.3 keV. Figure 1 shows EUV spectra for a central electron temperature, $T_{e0}$, of almost zero, 0.22 keV, and 0.34 keV. These spectra were obtained in a single discharge in a time sequence. As shown in Figure 1(a), when $T_{e0}$ was almost zero, line spectra with very low charge states, such as $W^{6+}$ at 216.2 Å and 261.4 Å, and $W^{7+}$ at 197–202 Å, were observed. Thereafter, as shown in Figure 1(b) ($T_{e0}$ = 0.22 keV), $W^{6+}$ and $W^{7+}$ disappeared and the line spectra of $W^{13+}$ were observed at 243.1 Å, 247.6 Å, 248.3 Å, and 249.1 Å. Although these $W^{13+}$ line spectra were observed for the first time in fusion plasma experiments, they were tentatively identified as $W^{13+}$ because the shape of the spectra is very similar to that of $W^{13+}$ observed in a Compact Electron Beam Ion Trap (CoBIT) experiment [2]. As $T_{e0}$ was further increased, the $W^{13+}$ peaks disappeared as shown in Figure 1(c) ($T_{e0}$ = 0.34 keV). The temperature range in which the low-charged ions appear is narrow, and this is thought to be one of the reasons why it has been difficult to observe them in high-temperature plasma experiments.

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References

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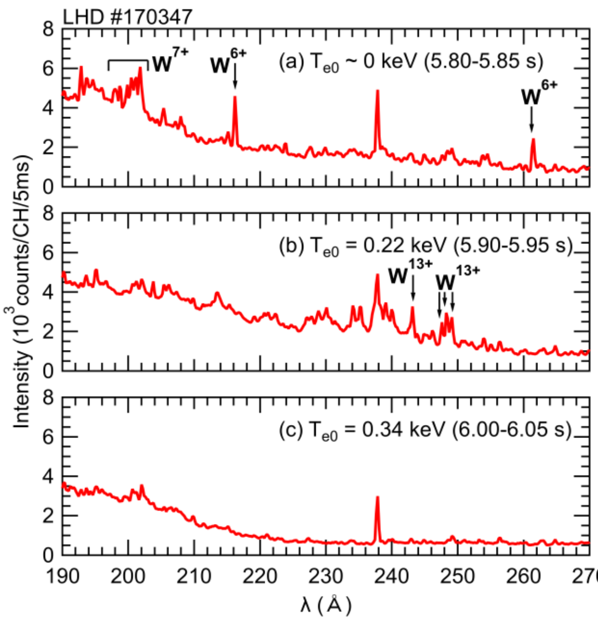


Figure 1. EUV spectra measured in LHD for $T_{e0}$ of (a) almost zero, (b) 0.22 keV, and (c) 0.34 keV.