7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Spectroscopic study of tungsten ions in LHD

I.Murakami[1,2], T. Oishi[3], D. Kato[1,4], H. A. Sakaue[1], Y. Kawamoto[1,2], T. Kawate[1,2], M. Goto[1,2], A. Sasaki[5]

[1] National Institute for Fusion Science, National Institutes of Natural Sciences

[2] Graduate Institute for Advanced Studies, SOKENDAI

[3] Department of Quantum Science and Energy Engineering, Tohoku University

[4] Interdisciplinary Graduate School of Engineering Sciences, Kyushu University

[5] Kansai Photon Science Institute, National Institutes for Quantum Science and Technology

e-mail (speaker): Murakami.izumi@nifs.ac.jp

Tungsten, used as a plasma-facing material in fusion devices, is sputtered by plasma particles and transported into central core plasma, causing electron temperature reduction due to high radiation power [1]. Tungsten behavior in plasmas should be examined by spectroscopic methods. Tungsten spectra in wide wavelength ranges have been measured in various fusion devices and electron beam ion traps (EBITs) (e.g. [2,3]). Spectral line identifications and spectral model calculations have been done. Theoretical studies on atomic structure and collision cross sections of tungsten ions also have been done but such data for low- and mid-charged ions are still missing.

We have measured spectra of W – W^{46+} ions from extreme ultraviolet (EUV) to visible wavelength ranges in Large Helical Device (LHD) by tungsten pellet injection [4]. LHD plasma is stable with such impurity injection. We can measure the time evolution of tungsten ion charge states due to the change in electron temperature caused by large radiation of tungsten ions.

For quantitative analysis of tungsten behavior, we have developed collisional-radiative (CR) models for tungsten ions [5,6]. The atomic data necessary for the CR models are calculated with the HULLAC atomic code [7]. The CR model calculations give the population density of excited states under the quasi-steady-state assumption, which is valid for plasma in which the time scale of the population changes is much shorter than the time scale of plasma changes. To explain the so-called unresolved transition array (UTA) feature at 4.5-7nm region, we included recombination processes in the CR model in which fine-structure levels for lower excited states and relativistic configuration average levels for higher excited states are considered.

Figure 1 shows a typical waveform of the W pellet injection experiment in LHD. The central electron temperature decreases due to the large radiation of tungsten ions after pellet injection. The measured EUV spectrum at 5.0s is shown in Fig.2 and the UTA feature is seen. Using the CR model calculations, we can synthesize EUV spectrum with ion abundance which is determined by fitting to the measured spectral peaks at 3-4nm. These peaks correspond to W^{25+} to W^{22+} spectral peaks [3]. The synthesized UTA profile looks very close to the measured one, although the profile wavelength is shifted short-wards, and profile heights are larger. This is big progress from previous work which cannot represent the measured UTA feature [5,6].

Detailed analysis of tungsten spectra with CR model calculations helps to understand W behavior in LHD plasmas.

References

[1] D. E. Post et al., At. Data Nucl. Data Tables 20, 397-439 (1977).
[2] R. Neu et al., Nucl. Fusion 45. 209-218 (2005).
[3] H. A. Sakaue et al., AIP Conf. Proc. 1430, 91 (2012).
[4] T. Oishi et al., Atoms 9, 69 (2021)
[5] I. Murakami et al., Nucl. Fusion 55, 093016 (2015).
[6] I. Murakami et al., Nucl. Mater. Energy 26, 100923 (2021).
[7] A. Bar-Shalom et al., Quant. Spectrosc. Radiat. Transfer 71, 169 (2001)

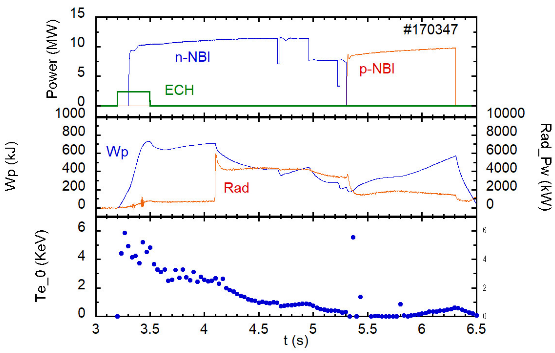

Figure 1. Waveform of W pellet injection experiment in LHD: (a) heating power of ECH, n-NBI, and p-NBI, (b) plasma stored energy, Wp, and total radiation power, Rad, and (c) central electron temperature. A W pellet was injected at 4.1s.

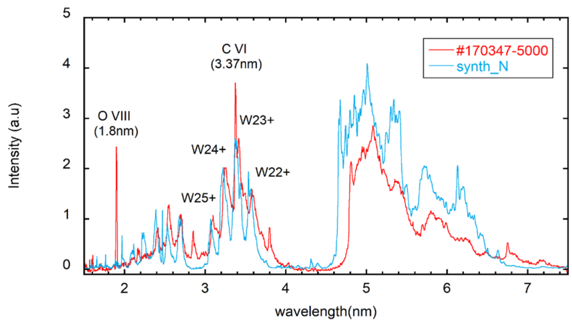

Figure 2. Measured EUV spectrum at 5.000s for the discharge #170347 (red line) and synthesized spectrum (blue line).