Identification of Forbidden Emission Lines from Highly Ionized Tungsten Ions in VUV Wavelength Range in LHD for ITER Edge Plasma Diagnostics

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Spectroscopic studies for emissions released from tungsten ions have been intensively conducted in the Large Helical Device (LHD) for contribution to the tungsten transport study in tungsten-divertor fusion devices and for the expansion of experimental database of tungsten line emissions [1]. Line emissions from tungsten ions in low charge states, W\textsuperscript{IV-\textsuperscript{VII}}, have been identified in the vacuum ultraviolet (VUV) range of 500 - 1500Å [2]. Also in the extreme ultraviolet (EUV) range of 10 - 500 Å, tungsten ions in low charge states, W\textsuperscript{V-WV\textsuperscript{VIII}}, as well as high charge states, W\textsuperscript{XLI-XLVI}, have been identified [3]. Recently, several magnetic-dipole (M1) lines of W\textsuperscript{XXIX-WXXXIX} were successfully observed in the VUV wavelength range. Tungsten ions are distributed in the NBI-heated LHD plasma by injecting a pellet consisting of a small piece of tungsten metal wire enclosed by a carbon or polyethylene tube [4]. While the electron temperature has a sudden drop due to the pellet injection, it can be recovered by ECH superposition together with continuous NBI heating. It is found that W\textsuperscript{XXXXVIII} line at 646.7 Å and W\textsuperscript{XXXXIX} lines at 532.9 Å and 559.0 Å are emitted when the central electron temperature ranges from 2 to 3 keV with relatively high intensity and isolated from other intrinsic impurity lines. The result is the first observation of the M1 forbidden lines of tungsten ions in the VUV wavelength range in fusion plasma experiments. Considering an application to ITER plasma diagnostics, tungsten ions of W\textsuperscript{37+} with the ionization energy, \(E_i\), of 1622 eV and W\textsuperscript{38+} with \(E_i\) of 1830 eV are expected to be distributed in the edge plasmas around the last closed flux surface including the scrape-off layer. Thus, observation of these lines as well as tungsten ions in the neighboring charge states could improve the tungsten diagnostics in ITER edge plasmas.

In the present study, the VUV wavelength spectra and the temporal evolution of the intensities of these newly observed M1 lines will be displayed together with emission from tungsten ions in various charge states such as W\textsuperscript{VI}, W\textsuperscript{VII}, W\textsuperscript{VIII}, W\textsuperscript{XVI}, W\textsuperscript{XXVII}, W\textsuperscript{XXV}, W\textsuperscript{XXVI}, W\textsuperscript{XXVII}, W\textsuperscript{XXVIII}, W\textsuperscript{XLII}, W\textsuperscript{XLIII}, W\textsuperscript{XLIV}, and W\textsuperscript{XLVI} observed simultaneously in a single discharge for a comprehensive understanding on tungsten impurity behavior. The line emissions listed above correspond to the charge states of tungsten ions distributed in ITER edge plasmas covering from the divertor legs to the edge pedestal.


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