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44 価および 45 価タングステンイオンの電離・再結合断面積の実験的な評価
Experimental evaluation of W^{44+} ionization and W^{45+} recombination cross-sections

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It has been decided that ITER (International Thermonuclear Experimental Reactor) will use tungsten (W) divertor from the day one because of the low tritium retention property. However, due to high atomic number (=74), W ions tend to accumulate at the plasma core, and strong line radiation from the W ions reduces the plasma temperature. Thus, one of the issues in plasma operation with W divertor is to prevent W ions from penetrating plasmas towards the core, and therefore, it is important to measure the W density at the core quantitatively. To determine the W density from measured W spectral line intensity, various atomic data for W ions are needed; ionization and recombination rates are needed in order to calculate fractional abundance of W^{q+} ion (q: charge number), and photon emission coefficients, which are calculated with a collisional-radiative model, are needed to determine W^{q+} density from the measured intensity of a W^{q+} spectral line. Hence, uncertainty of the determined W density heavily depends on uncertainties of the atomic data in addition to uncertainty of the measurement. However, in most cases, calculated W atomic data without uncertainty evaluation are used in the analysis. Therefore, it is very difficult to mention the uncertainty of the measured W density. This motivates experimental evaluation of the calculated W atomic data.

This talk presents comparison of a density ratio of W^{45+} to W^{44+} between measurement and calculation. The measurement was performed in mono-energy plasmas of Tokyo EBIT device, in order to determine the W^{45+} / W^{44+} density ratio from the intensity ratio of W^{45+} 4s-4p spectral line (6.2 nm) and W^{44+} 4s-4p spectral line (6.1 nm). One of the advantages of this method is cancellation of electron energy dependence of excitation cross-section from 4s (ground level) to 4p (first excited level), enabling direct conversion of the intensity ratio to a density ratio of W^{45+} over W^{44+} by using a coronal model.

On the other hand, the W^{45+}/W^{44+} density ratio can be calculated with W^{44+} ionization cross-section and W^{45+} recombination cross-section with the assumption of ionization equilibrium. For the W^{44+} ionization cross-section calculation, considered are direct

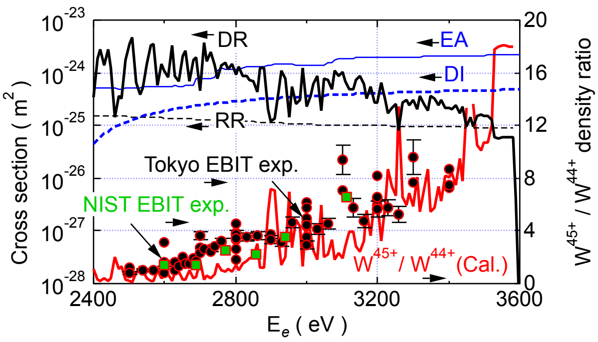

Fig. Calculated dielectronic recombination (DR), radiative recombination (RR), direct ionization (EI) and excitation-autoionization (EA) cross-sections (left axis), and comparison of calculated W^{45+} / W^{44+} ratio and measured ones (right axis).

ionization (DI) of 4s electron, and excitation to autoionization levels ($3d^9\ 4s^2\ nl$, etc) followed by autoionization to W^{45+} (excitation-autoionization, EA). As shown in the figure, the EA cross-section is higher by one order of the magnitude than the DI cross-section. For the W^{45+} recombination cross-section calculation, considered are radiative recombination (RR) to W^{44+} and dielectronic recombination (DR), which starts with electron capture by W^{45+} to doubly excited levels of W^{44+}. For the DR cross-section calculation, this work considers $3d^9$ 4s *nl n'l"* (*n* up to 16, *n'* up to 100, *l* and *l'* up to 12), $3p^5$ 4s *nl n'l"* (*n* up to 5), and 3s 4s *nl n'l"* (*n* up to 5) as the double excited levels. As shown in the figure, the DR cross-section is higher in the considered energy range than the RR cross-section. From these four cross-sections, the W^{45+}/W^{44+} density ratio is calculated. As shown in the figure, the calculated W^{45+}/W^{44+} density ratio is in good agreement with the measured one in the energy range over 3000 eV and in fair agreement below 3000 eV. Including further autoionization (AI) channels after the electron capture, for instance, AI to inner shell excited levels of W^{45+}, we could expect reduction of the DR cross-section, resulting in better agreement below 3000 eV. This is a future work.