§15. Spectral Lines of C^{2+} Ions Measured in the LHD Plasmas

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In low temperature plasmas such as divertor or process plasmas, emission from impurities is important for plasma diagnostics and plasma modeling. We studied dielectronic recombination processes for carbon L-shell ions. We made a collisional radiative model for carbon L-shell ions including both ionization/excitation and recombination processes. We apply this model to spectra measured in the LHD.

Data for dielectronic recombination (DR) to excited states are available up to n = 6 distinguishing the configuration, spin and terms of L-shell ions: C^{+0}, C^{+1} and C^{+2}[1 - 3]. DR data are available in NIFS Database (http://dbshino.nifs.ac.jp). The DR rates remain large for highly excited states up to n = 100 where n is the principal quantum number.

Using the new data, we construct a collisional radiative model for C^{2+} ions including the levels up to n = 5. Since DR rate remains large to high n, we used a critical limit n_{th} (Griem's formula) to truncate DR rate for ionizing plasma. When $n_{th} > 5$, transitions to $n_{th} > n > 5$ are summed and transferred to n = 4. For recombining plasma, when $n_{th} < 5$, an averaged n = 5 level having LTE populations is assumed.

We derived effective ionization, recombination and emission rate coefficients which depend on the electron density as well as the electron temperature. Effective ionization rate coefficient is increased by ladder-like excitation and ionization at high densities. Density effects begin from 10^{13} cm^{-3} and saturate at 10^{18} cm^{-3}. Effective recombination rate coefficient is decreased by ladder-like excitation and ionization at intermediate density (< 10^{16} cm^{-3}) and increased at high densities (> 10^{18} cm^{-3}). Radiation loss rate coefficient (Watt cm^3/ion/electron) in ionizing plasmas decreases at high densities. Radiation loss rate coefficient in recombining plasmas decreases at high densities for $T_e > 2$eV.

We calculated the density and temperature dependence of intensities for the emission lines for plasma diagnostics. The line intensity ratios of the triplet lines I_t ($2s2p\ ^3P - 2p^2\ ^3P$, 1175A) to the resonance line I_r ($2s^2\ ^1S - 2s2p\ ^1P$, 977A) are always smaller than one for ionizing plasmas and larger than one for recombining plasmas. We study the intensity ratios with measured spectra from LHD.

Time dependent UV Spectra (~1000A) were measured for plasmas heated by ECH (#15080) every 184 ms with 20ms exposure time. The spectra from plasmas heated by NBI (#28967) are also measured every 100ms with 33ms exposure time .

From the intensity ratios of emission lines $I(2p^2\ ^3P - 2s2p\ ^3P)$ / $I(2s2p\ ^1P - 2s^2\ ^1S)$ for #15080, the spectra can be classified as ionizing or recombining plasma as shown in Fig.1. We obtain plausible electron temperatures from the CIII spectra to be Te = 30 – 40 eV for ionizing phase and Te = 2 – 3 eV and Te ~ 0.1 eV for recombining phase. For NBI (#28967) case, the spectra are classified always as ionizing plasma even after radiation collapse because the intensity ratios are always below one as shown in Fig.2. Electron temperature is estimated Te = 40 eV --> 20 eV before radiation collapse and Te ~ 3 eV at radiation maximum phase. After radiation collapse, temperature drops to 2 eV.

We plan to study measured line emissions for H, He, C, O and Ne ions in the transient plasma. LHD plasma is a good source to study recombining plasmas. In this work we advance to more direct application of our techniques and codes to plasma diagnostics and plasma modeling.

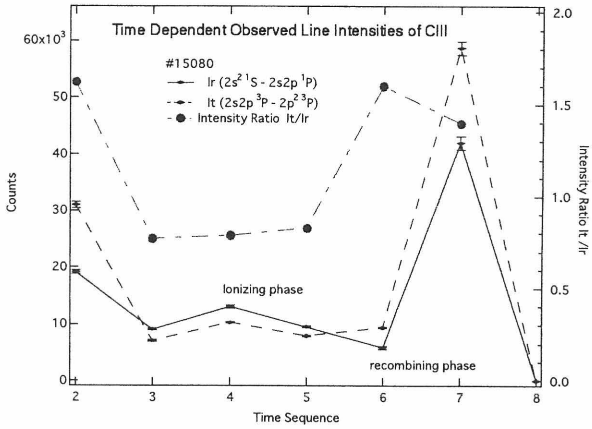

Fig.1 Time dependent observed CIII line intensities and ratios for ECH heated plasma.

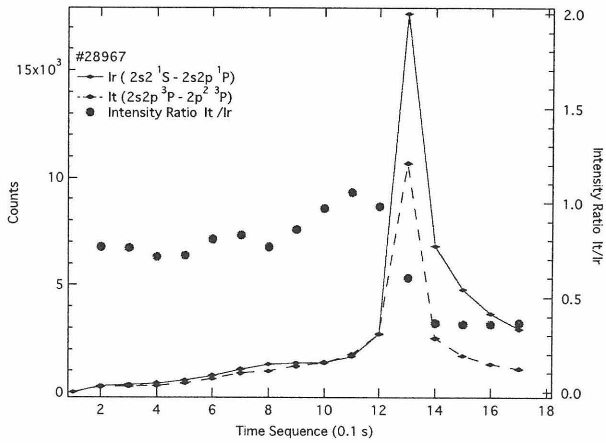

Fig.2 Time dependent observed CIII line intensities and ratios for NBI heated plasma.

References

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