§17. Development of a Collisional-Radiative Model of Oxygen Ions for Plasma Diagnostics

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Oxygen ions are major impurities in laboratory plasmas. Spectral line intensity ratios can be used for diagnosing plasma temperature and density, or ion abundance. The relationship between line intensities and plasma temperature and density is usually given by a theoretical kinetic model. We are making a collisional-radiative model for oxygen ions for the purpose of plasma diagnostics. We make a detailed collisional-radiative model for Be-like oxygen ions (OV) including the effect of recombination from Li-like oxygen ions[1)] and inner-shell ionization from B-like oxygen ions. We also make a collisional-radiative model for ionizing plasma for all oxygen atoms and ions. The former model is applied to plasma diagnostics. The collisional-radiative models require a large set of atomic data. We calculate atomic data with Hullac code for excitation and inner-shell ionization rate coefficients and radiative transition probabilities. We calculated dielectronic recombination rate coefficients of OV ion with Cowan code[2)].

The intensity ratio of OV(2s2p ^{3}P -2p^2 ^{3}P 76nm)/OV(2s^2 ^{1}S – 2s2p ^{1}P 63nm) is less than 1 if the population densities of OV excited states are dominated by the excitation from the ground state of OV ("ionizing component"). If plasma is in recombining phase, then the ratio becomes larger than 1[1)]. In our previous work[1)] we examined the measured ratio for the shot #15078 from the 3rd LHD experiment campaign and the ratio was 2.2 during the steady-state phase of plasma with nearly constant electron density and stored energy. Such a large ratio could not be explained with a simple collisional-radiative model with ionizing and recombining components, since it was difficult to expect the plasma was dominated by recombining component[1)]. Thus we next included the contribution of the inner-shell ionization from OIV to the excited states of OV. This inner-shell ionization component from OIV ions allowed us to explain the large ratio.

In this work we examine the same intensity ratio of the similar plasmas with long steady-state phase. In the 9th LHD experiment campaign we measured EUV spectra for LHD plasmas and observed OIII, OIV, OV, OVI lines as well as Ly series of hydrogen and CII and CIII lines.

The shot numbers and obtained ratios of OV(76nm)/OV(63nm) in steady－state phase are listed in Table 1. Similarly to the previous work, the ratios are larger than 1 and we expect the inner-shell ionization component is important again. From the theoretical work, the dependence on the electron density of this intensity ratio is quite weak and the difference of the ratios from the three shots is difficult to explain with the different electron density. Figure 1 shows temperature dependence of the intensity ratio when $n_e=10^{19}m^{-3}$. The measured ratios can be explained with a combination of electron temperature and ion abundance ratio n(OIV)/n(OV). More detailed analysis with OIV lines will be required to determine both parameters.

Table 1 Measured intensity ratio, OV(76nm)/OV(63nm) from the LHD experiments.

Shot number	OV(76nm)/OV(63nm)	Ne(max) ($10^{19}m^{-3}$)	Wp(max) (kJ)
56839	1.53 ± 0.059	4.652	527.1
56840	1.30 ± 0.098	3.072	609.6
56841	1.13 ± 0.183	2.069	447.2

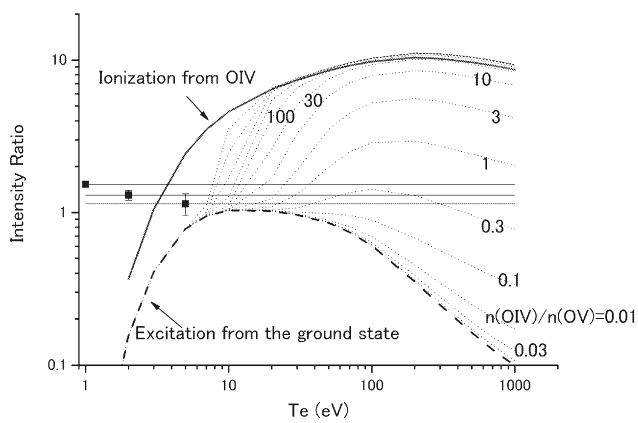

Fig.1 Intensity ratio of OV(76nm)/OV(63nm) as a function of electron temperature for electron density $n_e=10^{19}m^{-3}$. Solid thick line is the ratio of inner-shell ionization component from OIV. Thick dashed line is for excitation component from the ground state of OV. Dotted lines are composed ratios of two components with different ion density ratios from 0.003 to 10000. Three horizontal lines with squares and error bars are measured ratio from LHD experiments in Table 1.

References
1) I.Murakami et al., J. Plasma Fusion Res. SERIES, 5 (2002) 171.
2) I.Murakami et al., Canadian J. Phys. 80 (2002) 1525.