§15. Study of Optimum Conditions and Atomic and Molecular Reactions on LHD Closed Divertor

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The closed Helical Divertor (HD) in LHD is planned to accomplish an active neutral control to improve plasma confinement and to sustain high performance long pulse discharges. The neutral pressure in the closed HD has to be enhanced by more than one order of magnitude compared to that under the present open divertor condition. In high gas pressure, the vibrationally excited hydrogen molecules, $H_2(v'')$, in their electronic ground state play a significant role in the divertor plasma because of the increase in ionization and dissociation rate coefficients. In order to understand the role of the $H_2(v'')$ in the divertor plasma, measurements of the ground-state vibrational temperature of hydrogen molecules, T_{vib}, have been given by vacuum ultraviolet (VUV) lights in the spectral range 80-180 nm. In the VUV wavelength region from 80 to 180 nm, there are two strongest band system for H_2 (the Lyman-band and the Werner-band) for atomic hydrogen. In this paper, T_{vib} can be found which results in a best fit the calculated VUV spectrum to the observed relative intensities of VUV spectrum.

The experiment was performed in the linear plasma device TPD-SheetIV.[1)] Ten rectangular magnetic coils formed a uniform magnetic field of 1.0 kG in the experimental region. The hydrogen plasma was generated at a hydrogen gas flow of 75 sccm, with a discharge current of 30-100 A. The neutral pressure P_{div} in the experimental region was controlled between 0.01 and 2.0 Pa with a secondary gas feed. The sheet plasma flowed from the plasma source along the magnetic field to a floating endplate located about 1.0 m downstream.

Electron density and electron temperature were measured using a planar Langmuir probe in front of the endplate. The rate coefficients are calculated using cross sections over a Maxwellian energy distribution faction of the electrons. Through a viewing port installed in the sidewall of the experimental region, the plasma is observed using the VUV spectrometer (20cm Seya-Namioka VUV Spectrometer, nominal resolution of 0.1nm) with a differential pumping system by a 150 l/s turbo-pump and a charge-coupled device (CCD) camera. The VUV spectra from electronically excited hydrogen molecules were detected 3 cm from the target plate.

The corona model used to calculate the population distribution of the vibrational levels resulting from a Boltzmann population distribution in the ground state characterized by a temperature of hydrogen molecule. The calculated relative intensities of VUV spectrum of the transitions from $B^1\Sigma_u^+(v') \rightarrow X^1\Sigma_g^+(v'')$ (the Lyman-band), $C^1\Pi_u(v') \rightarrow X^1\Sigma_g^+(v'')$ (the Werner-band), and $D^1\Sigma_u(v') \rightarrow X^1\Sigma_g^+(v'')$ are given by

$$I_{Xv''}^{Bv',Cv',Dv'} = \frac{A_{Xv''}^{Bv',Cv',Dv'}}{\sum_{v'} A_{Xv''}^{Bv',Cv',Dv'}} \frac{hc}{\lambda_{Xv''}^{Bv',Cv',Dv'}} n_e \sum_{v} \left\{ c_{Xv}^{Bv',Cv',Dv'} n_{Xv} \, exp\left[-\frac{G_X(v)}{kT_{vib}^X} \right] \right\},$$

where, $A_{Xv''}^{Bv',Cv',Dv'}$ is spontaneous emission coefficient. $\lambda_{Xv''}^{Bv',Cv',Dv'}$ is the wavelength of the measured line, $G_X(v)$ is the vibrational energy in the $X^1\Sigma_g^+$ state, $c_{Xv}^{Bv',Cv'Dv'}$ is the electron impact excitation rate from the $X^1\Sigma_g^+(v)$ state to the $B^1\Sigma_u^+(v')$, $C^1\Pi_u(v')$, and $D^1\Sigma_u(v')$ states, respectively.[2,3)]

Figure 1 shows the VUV spectra of the intensity compared to the predicted result (except the Lyman α, β, γ for atomic hydrogen) by calculation of model with that of the experimental result at T_e = 14 eV, $n_e = 9.3 \times 10^{17} m^{-3}$ and P= 0.07 Pa. The solid line represents the experimental results. The dotted line and the dashed-dotted line give the calculated results with radiation trapping and without one, respectively. T_{vib} can be estimated which results in a best fit to the observed relative intensities of VUV spectrum in the range from 90 nm to 150 nm. The calculated values and the experimental results show good agreement, provided that radiation trapping effects are taken in account.

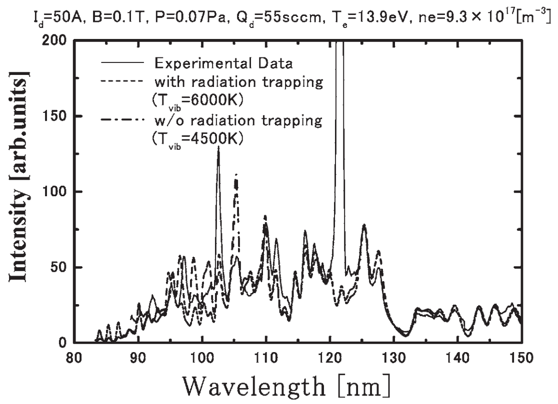

Fig. 1 VUV spectra of the intensity compared to the predicted result by calculation of model with that of the experimental result.

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