§9. Production Mechanism of D⁻ Ions and Evaluation of D⁻ Ion Current Extraction

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In a tandem volume source, H^- ions are generated by the dissociative attachment of slow plasma electrons e_S ($T_e \backsim$ 1eV) to highly vibrationally excited hydrogen molecules $H_2(v")$ (effective vibrational level v"$\geqq 5 \backsim 6$). These $H_2(v")$ are mainly produced by collisional excitation of fast electrons e_f with optimum energy of about 40 eV. Namely, H^- ions are produced by the following two step process, i.e. $H_2(v")$ production and H^- formation:

$$H_2(X^1\Sigma g, v"=0) + e_f \rightarrow H_2^*(B^1\Sigma u, C^1\Pi u) + e_f' \quad (1a)$$
$$H_2^*(B^1\Sigma u, C^1\Pi u) \rightarrow H_2(X^1\Sigma g, v") + h\nu \quad (1b)$$
$$H_2(v") + e_S \rightarrow H^- + H \quad (2)$$

Production process of D^- ions is believed to be the same as that of H^- ions described above. We have studied relationship between negative ion production (i.e. H^- and D^- ions)[1-3] and plasma parameters across the magnetic filter (MF). By varying the intensity of the MF, axial distributions of T_e and n_e in both H_2 and D_2 plasmas are changed strongly in the downstream, i.e. extraction region [3, 4].

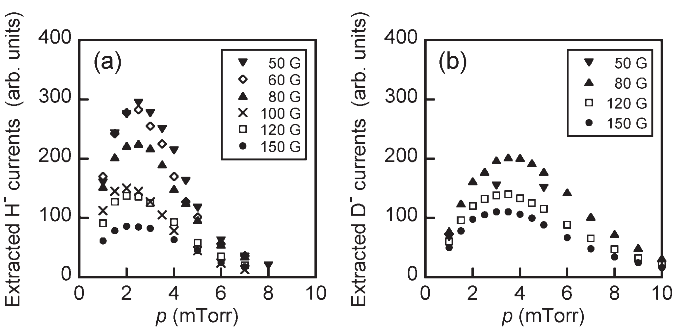

Fig. 1. Pressure dependences of extracted (a) H^- and (b) D^- currents. Experimental conditions are as follows: V_d = 70 V, I_d = 5 A, and extraction voltage V_{ex} = 1.5 kV. Parameter is the magnetic field intensity of the MF.

Figure 1 shows the pressure dependence of extracted negative ion currents from (a) H_2 and (b) D_2 plasmas. In both cases, as described above, the negative ion currents are varied due to the change in plasma conditions with decreasing the MF intensity. In both cases, there are also some optimum pressures. With increasing gas pressure, negative ion currents (i.e. the H^- current, I_{H^-} and the D^- current, I_{D^-}) increase in their magnitude, reach the maximum value, and then, decrease. Decreasing MF intensity, the optimum pressure p_{opt} shifts to higher pressure. For D^- production, p_{opt} is from 0.27 to 0.47 Pa. On the other hand, for H^- production, p_{opt} is from 0.2 to 0.27 Pa. Optimum pressure in D_2 plasmas is slightly higher than one in H_2 plasmas.

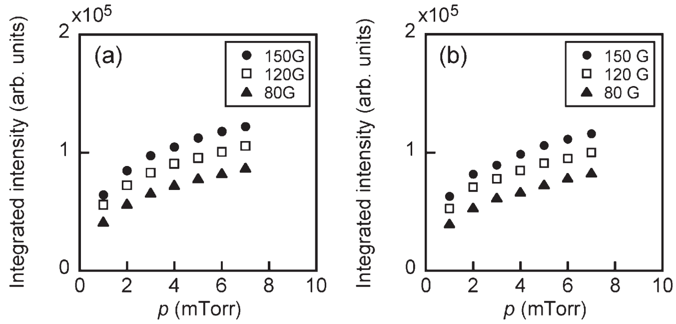

Fig. 2. Pressure dependence of integrated intensities of VUV spectra from (a)H_2 and (b)D_2 plasmas, where V_d = 70 V and I_d = 5 A. Parameter is the magnetic field intensity of the MF.

Figure 2 shows pressure dependence of integrated intensities of VUV spectra from H_2 plasmas, where the intensity of the MF is a parameter. The VUV emissions increased gradually with gas pressure. The values of integrated intensities with 150 G are highest in the entire region of gas pressure, and intensities are decreased with the intensity of the MF. As shown in Fig. 1, the extracted H^- and D^- currents vary with the intensity of the MF. It is noted that the integrated intensity of the VUV emissions and the extracted H^- and D^- currents vary in opposite directions, respectively, when the MF is varied[4]. Numerical calculations show that the VUV emissions associated with the process (1b) are a function of the fast electron density. Therefore, as the VUV measurements were made in the source region, these should be higher with B_{MF} = 150 G than with B_{MF} = 80 G. We have also confirmed the same tendencies on the discharge power dependences between VUV emissions and H^- and D^- currents as those on pressure dependences above-mentioned MF intensities.

According to the results shown in Figs. 1 and 2 and related discussions, our present picture on negative ion production is as follows: In the present experimental conditions with low-pressure, electron-neutral collision mean free paths for destruction of the vibrationally excited molecules (i.e. ionization and dissociation collisions) are a few tens of centimeters. Therefore, sufficient amount of H_2 (v") and D_2 (v") are transported to the extraction region, although H_2 (v") and D_2 (v") are produced by the collisions between the ground state molecules and fast primary electrons in the source region. The negative ions are produced by the process (2) of slow plasma electrons to H_2 (v") and D_2 (v") in the extraction region. Namely, negative ion production is rate-determined by the plasma parameters in the extraction region.

References

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