§4. 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 ($T_e \sim$ 1eV) to highly vibrationally excited hydrogen molecules $H_2(v")$ (effective vibrational level $v" \geqq 5 \sim 6$). 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, 2] and plasma parameters controlled by the magnetic filter (MF). 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 region, i.e. the extraction region[3, 4].

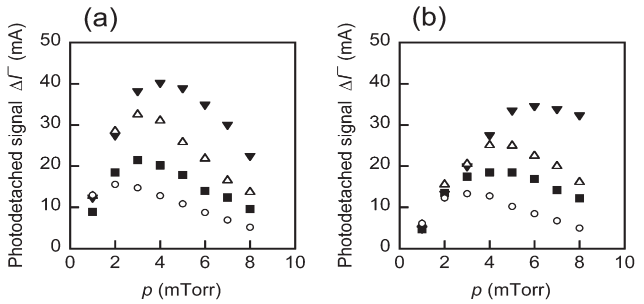

Fig. 1. Pressure dependence of negative ion densities in the vicinity of the extraction electrode: (a) H^- density and (b) D^- density. Parameter is the magnetic field intensity B_{MF} of the MF, B_{MF}=50G(▼), 80G(△), 120G(■) and 150G(○). Experimental conditions are as follows: discharge voltage V_d = 70 V and discharge current I_d = 10 A.

Figure 1 shows the pressure dependence of negative ion densities in (a) H_2 and (b) D_2 plasmas. In both cases, as described above, the negative ion densities are varied due to the change in plasma conditions with changing the magnetic field intensity B_{MF} of the MF. As shown clearly, there are some optimum pressures. With increasing gas pressure, negative ion densities increase in their magnitude, reach the maximum value, and then, decrease. Decreasing the B_{MF}, the optimum pressure p_{opt} shifts to higher pressure. For D^- production, p_{opt} is changed from 3 to 6 mTorr. On the other hand, for H^- production, p_{opt} is from 2 to 4 mTorr. Optimum pressure in D_2 plasmas is slightly higher than one in H_2 plasmas.

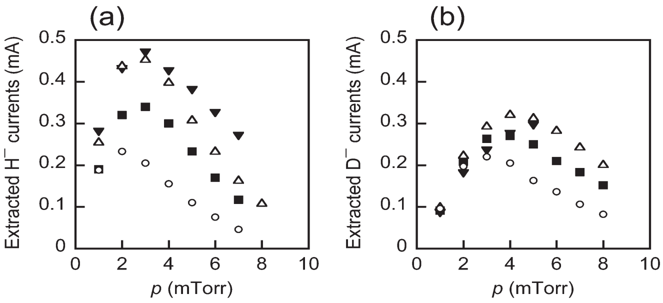

Fig. 2. Pressure dependence of extracted (a)H^- and (b)D^- currents, corresponding to the negative ion densities shown in Fig. 1, where extraction voltage V_{ex} = 1.5 kV.

The corresponding extracted negative ion currents are shown in Fig. 2. As a whole, pressure dependence have the same feature as ones of negative ion production shown in Fig. 1 although details are slightly changed.

On negative ion production, intensity of the VUV emission caused by the process (1b) is measured. The values of integrated intensities in the source region are increased with increasing gas pressure and the B_{MF}. As shown in Fig. 1, the H^- and D^- densities vary with the B_{MF}. It is noted that the integrated intensity of the VUV emissions and the H^- and D^- densities vary in opposite directions, respectively, when the B_{MF} is varied[3]. Numerical calculations show that the VUV emissions associated with the process (1b) are a function of fast primary electrons, i.e. its density and behaviour[4]. With increasing the B_{MF}, fast electron density in the source region is increased and then the collisions with process (1b) are also increased. Then, the intensity of VUV emission increases with the B_{MF} as ones observed in the present experiment.

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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