§21. Measurement of the Negative Ion and Control of Recombination Plasma in the LHD Divertor

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The detached plasma is a very complex phenomenon with atomic and molecular collision processes. It is observed that the mutual neutralization in MAR via H^- ion formation, which is produced by dissociative electron attachment to $H_2(v)$, occurs in the periphery of the plasma where cold electrons (~1 eV) are found [1]. In other words, the negative ions, that is hydrogen negative ion (H^-) and deuterium negative ion (D^-), play an important role in the mutual neutralization of MAR, providing a new method of controlling detached plasmas [2].

The following parameters are measured: the hydrogen negative ion density n_{H^-}, the electron density n_e, the electron temperature T_e, and the Lyman-band and Werner-band emission spectra in the vacuum ultraviolet (VUV) wavelength region from electronically excited hydrogen molecules $H_2(B^1\Sigma_u, C^1\Pi_u)$. The measured n_{H^-} was compared with the theoretical calculation based on the rate equation of the transport of vibrationally excited hydrogen molecules[3,4].

In order to clarify the behaviors of negative ions in the sheet plasma, we evaluated the negative ion density from a steady state solution of the following simple rate equation:

$$n_{H^-} = \frac{\sum_{5 \le v'' \le 9} n_{H_2^*(v'')} n_e < \sigma \upsilon >_{DA}}{n_e < \sigma \upsilon >_{ED} + n_{H^+} < \sigma \upsilon >_{MN} + \dfrac{1}{\tau_{H^-}}}, \qquad (1)$$

where $< \sigma \upsilon >_{DA}$, $< \sigma \upsilon >_{ED}$, and $< \sigma \upsilon >_{MN}$ are rate coefficients for dissociative attachment (DA), electron impact detachment (ED), and mutual neutralization (MN), respectively. The τ_{H^-} is the lifetime of H^- ions. These rate coefficients are calculated by cross sections over a Maxwellian energy distribution function of the electron. The rate coefficient varies exponentially with T_e for the temperature range of these experiments and therefore serves as a very sensitive measure of electron temperature.

To model the negative ion density in equation (1), rate coefficients $< \sigma \upsilon >_{ED}$ and $< \sigma \upsilon >_{MN}$ are calculated by cross sections over a Maxwellian energy distribution function of the electron, which can be solved numerically given measured values of n_e, T_e. Figure 1 shows the special distribution of measured hydrogen negative ions n_{H^-} and calculated hydrogen negative ions $<n_{H^-}>$ in the Y-direction at the gas pressure of 0.45 and 3.0 mtorr. Both n_{H^-} and $<n_{H^-}>$ are localized in the periphery region (Y =10-20 mm). The value of $<n_{H^-}>$ is on the same order with the experimental results in the Y-direction. The vibrationally excited hydrogen molecules $H_2^*(X^1\Sigma_g^+(v>5))$ are produced by the collision between the H_2 and high energy electrons at the center of the plasma and transported to the periphery region of the plasma. After that, negative ions of hydrogen atom are produced by dissociative electron attachment of low energy electrons to vibrationally excited hydrogen molecules $H_2^*(X^1\Sigma_g^+(v>5))$ in the periphery region of plasma.

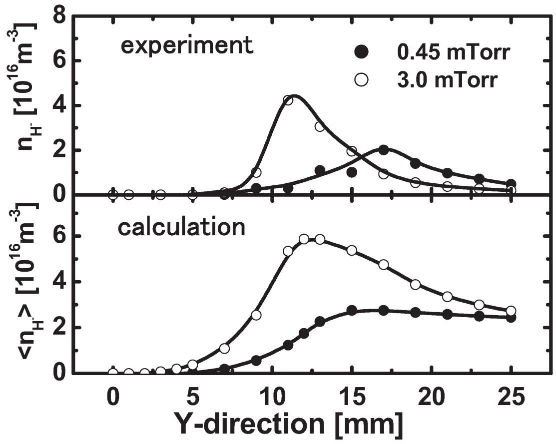

Fig.1 Spatial distributions of measured n_{H^-} and calculated number of hydrogen negative ions $<n_{H^-}>$ at gas pressures of 0.45 and 3.0 mTorr.

Reference

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2) Ono M., Tonegawa A. et al: J. Nucl. Mater. 337-339 (2005)264.
3) Tonegawa A. et al: J.Korean Phys.Soc. 49 (2006) 133.
4) Tonegawa A. Et al: Jpn.J.Appl.Phys. 45 (2006) 8212.