§ 11. High Efficiency Gas Divertor Control by Molecular Activated Recombination Process

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The control of the detached plasma is thought to be a key issue in order to reduce the heat flux at divertor plates. In a detached plasma, the recombination process associated with molecular reactions, such as the molecular activated recombination (MAR) involving a vibrationally excited hydrogen molecule, has been emphasized in theoretical investigation and modeling. Especially, the negative ion plays an important role in the mutual neutralization of MAR[1], providing a new method of controlling detached plasma.

In this paper, we present the experimental evidence of negative ions formation of hydrogen atom on hydrogen detached plasma in the linear divertor plasma simulator, TPD-SHEET-IV (Test Plasma produced by Directed current for SHEET plasma) [2]. In particular, we studied by measuring the UV spectroscopy and hydrogen negative ion density by photodetachment.

The experiment was performed in the linear plasma TPDSHEET–IV. This device was divided into two regions: the sheet plasma source region and the experimental region. Hydrogen sheet plasma was produced by the modified TP-D type dc discharge. The anode slit was 2 mm thick and 40 mm wide. The strength of the uniform magnetic field in the experimental region formed by ten rectangular magnetic coils was of 0.7 kG. The sheet plasma was terminated by the electrically floated and water-cooled target plate, which was made of stainless steel at the axial position of z = 0.7 m from the discharge anode electrode. The hydrogen plasma were generated with the hydrogen gas flow of 70 sccm at the discharge current of 50A. The neutral pressure P_{Div} in the experimental region was able to be controlled from 0.1 to 20 mtorr by feeding a secondary gas. The electron temperature and the electron density were measured by the Langmuir probe. The heat load, Q, was measured with the calorimetric method. A cylindrical probe made of tungsten (0.4 x 2 cm) was used to measure the spatial profiles of H^- by a probe-assisted laser photodetachment method. The uv emission spectra of H_2 molecules were detected at the axial position of 3 cm apart from the target plate.

Fig.1 shows the typical uv emission spectrum of H_2 molecules in the central region of the sheet plasma on hydrogen as pressure P_{Div} ~ 3 mtorr. The two important electric transitions occurring in this region are indicated. The spectra of H_2 with Lyman-band system ($B^1\sum_u^+ \rightarrow X^1\sum_g^+$) and Werner-band system ($C^1\prod_u \rightarrow X^1\prod_g^+$) are observed in the center region with hot electron (T_e= 10-15 eV). They are the H_2 molecules of higher-vibrational states around v >4. Also, the value of n_{H^-} is localized in the outer region (y=10-20 mm) existing cold electrons ($n_e \sim 5x10^{17}$ m^{-3}, Te= 3-5 eV). The peak value of n_{H^-} is $1.2x10^{17}$ m^{-3} and the ratio of n_{H^-}/n_e in the outer region goes up to over 20%. These results can be well explained by taking the mutual neutralization between the negative and positive ions of MAR in the detached plasma into account.

These experimental results suggest that the negative ions are produced in the circumference of the sheet plasma through dissociative attachment of electrons to vibrationally excited molecules (v >4) on MAR.

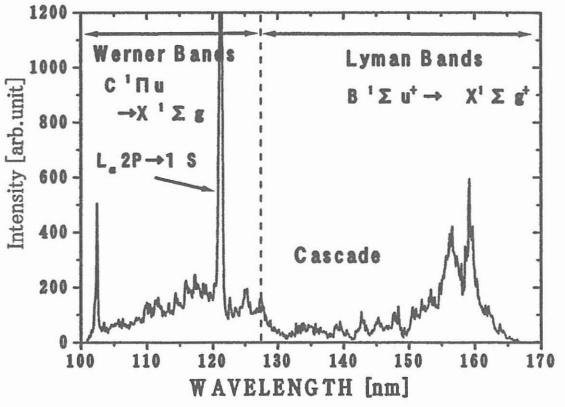

Fig.1 Observed uv emission spectrum of H_2 molecules in the central region of the sheet plasma.

Refernces

[1] Tonegawa, A. et al: J. Nuclear Materials, 313-316, (2002) 1046.

[2] Tonegawa, A. et al: J.Advanced Science, 11 (1999) 232.