§25. 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. Recently, we have presented the experimental observation of the spatial structure of MAR in the detached hydrogen plasma at the periphery of the plasma on the linear divertor plasma simulator, TPD-SheetIV[1]. It is shown from the results of mass-analysis (H^+, H_2^+, H_3^+) that dissociative recombination is dominant in the center of the plasma over a range of low gas pressures [2]. At the same time, 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. In other words, H^- ions play an important role in the mutual neutralization of MAR, providing a new method of controlling detached plasmas. In this report, we have developed a new method to control a detached plasma based on utilizing H^- ions which are formed as part of the MAR mutual neutralization process occurring in the periphery of the plasma [3].

The experiment was performed in the linear divertor plasma simulator TPD-SheetIV. Ten rectangular magnetic coils formed a uniform magnetic field of 0.08 T in the experimental region. The neutral pressure P_{Div} in the divertor test region was controlled between 0.1 and 20 mtorr with a secondary gas feed. The heat load on the target plate Q was measured by a calorimeter. At a discharge current of 100 A, the value of Q reaches about 1 MW/m^2. A cylindrical probe made of tungsten was used to measure the spatial profiles of the negative hydrogen ion density by a probe-assisted laser photodetachment method. At a repetition rate of 50 Hz, the Nd-YAG laser had an energy per pulse of 100 mJ.

The concept of control of a detached plasma using negative ions can be illustrated through the following steps; (1) measure the experimental data related to the minimum and maximum basic parameters (gas pressure P_{Div}, heat load Q) in order to determine for controlled region, (2) control the secondary gas-flow rate G_{Div} rapidly so as to maximize the value of the negative ion density n_{H^-}, (3) carry out a real time feedback control in order to maintain a steadily detached plasma in the neighborhood of the target plate.

By defining Q_{att} as the heat load in attached plasma and Q_{pm} as the heat load at the maximum negative ion density for a particular pressure n_{H^-max}, we can express the reduction of the heat load as the ratio of Q_{att} to Q_{pm}, that is, $\Delta Q = Q_{pm}/Q_{att}$. The variations of n_{H^-max}, heat load Q_{att}, Q_{pm}, and the head load radio ΔQ with the discharge current I_d is shown in Fig. 1. As I_d changes from 50 to 100 A, Q_{att} increases from 0.32 to 1.1 MW/m^2. At the same time, n_{H^-max} increases linearly from 1.8 to 5.1 $x10^{16}$ m^{-3} and Q_{pm} increases from 0.1 to 0.4 MW/m^2. Therefore, ΔQ remains nearly constant at around 30-40 % with increasing the heat load to the target. These results indicate that this new way of controlling a detached plasma, based on the feedback control of the negative hydrogen ion density in the high density part of the plasma, is promising. The new system has achieved the goal of reducing the target heat flux while simultaneously minimizing the amount of gas puffed in a detached plasma without radiative and three-body recombination processes.

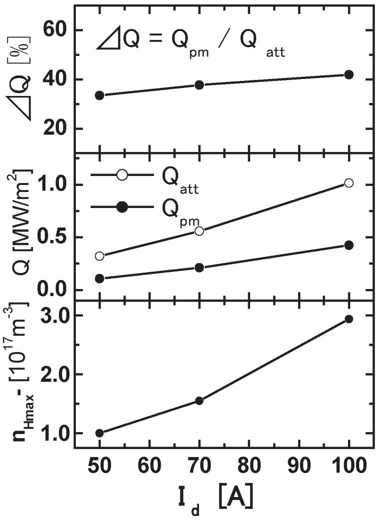

Fig.1 The variations of n_{H^-max}, heat load Q_{att}, Q_{pm}, and the heat load ratio ΔQ with the discharge current I_d.

Reference

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