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

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We have presented the experimental observation of the spatial structure of MAR in the detached hydrogen plasma at the periphery of the plasma in the linear divertor plasma simulator, TPD-SheetIV [1]. It is observed that the mutual neutralization in MAR via hydrogen negative 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 [2]. In fusion experiments, the negative ions, that is deuterium negative ion (D^-), play an important role in the mutual neutralization of MAR, providing a new method of controlling detached plasmas.

In this paper, we have developed a new method to control a detached plasma based on utilizing D^- ions which are formed as part of the MAR mutual neutralization process occurring in the periphery of the deuterium plasma on the linear divertor plasma simulator, TPD-SheetIV.

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 0.6 MW/m^2. A cylindrical probe made of tungsten was used to measure the spatial profiles of the deuterium negative ion density n_{D^-} 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 n_{D^-}, (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_{D^-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_{D^-max}, heat load Q_{att}, Q_{pm}, and heat load ratio ΔQ with the discharge current I_d is shown in fig. 1. In the deuterium plasma, Q_{att} increases from 0.1 to 0.58 MW/m^2 and n_{D^-max} is nearly constant value with increasing I_d. In spite of these characteristics of the deuterium negative ions, ΔQ gradually decreases from 60 to 40 % with increasing heat load to the target.

Similarly to the characteristics of ΔQ on the detached hydrogen plasma[3], these results indicate that this new way of controlling a detached deuterium plasma, based on the feedback control of the relative negative ion density in the high density part of the plasma. The new system has achieved the goal of reducing the target heat flux while simultaneously minimizing the amount of gas puffed in a detached hydrogen or deuterium plasma without radiative and three-body recombination processes.

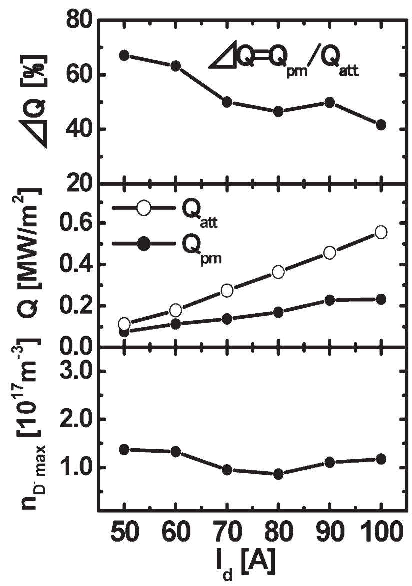

Fig.1 The variations of n_{D^-max}, heat load Q_{att}, Q_{pm}, and the heat load ratio ΔQ with the discharge current I_d.

Reference
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3) Ono,M, Tonegawa,A, Kumita,K, Shibuya,T and Kawamura,K, J. Nucl. Mater. **337-339,** (2005) 264.