Electron Temperature and Density Distributions in Detachment Experiments on a Divertor Simulation Experimental Module of GAMMA 10/PDX

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Distributions of electron temperature $T_e$, density $n_e$ and ion saturation current $I_{is}$ are measured in detachment experiments with $H_2$ and impurity (Xe) gas injection on a divertor simulation experimental module of GAMMA 10/PDX. As Xe gas is increased, $T_e$ and $I_{is}$ decrease but $n_e$ once increases and then decreases especially near the target plate, which suggests the detachment. At high Xe gas amount, the region where $n_e$ compensated for magnetic flux expansion decreases toward the target plate appears, which suggests recombination is dominant.

1. Introduction
Radiation cooling and the detachment in the divertor to reduce heat load are important issues for a fusion reactor [1]. However, physical mechanism of the detachment has not been sufficiently understood [2]. Therefore, we study radiation cooling and the detachment utilizing high temperature (electron ~ 100 eV, ion ~ 10 keV [3]) core plasma of tandem mirror device GAMMA 10/PDX [4-6]. Recently, a divertor simulation experimental module (D-module) has been installed in GAMMA 10/PDX [7,8]. Plasma temperature and density distributions including magnetic field direction are important for the detachment study [9]. Thus, in this study, electron temperature and density distributions are measured in detachment experiments with gas injection on the D-module.

2. Experimental Apparatus
Figure 1 shows a schematic view of GAMMA 10/PDX and the D-module. The D-module has a tungsten V-shaped target plate (open-angle of 45 degree in this work), $H_2$ gas injection ports, impurity gas (Ar, Xe, Ne, N$_2$, etc.) injection ports, and a closed divertor structure, which are useful for the radiation cooling and detachment study.

![Fig.1. Schematic of GAMMA 10/PDX and D-module.](image)

3. Experimental Results and Discussion
Figure 2 shows distributions of electron temperature $T_e$, density $n_e$ and ion saturation current $I_{is}$ measured by Langmuir probes in $H_2$ and Xe gas injection experiments. $T_e$ decreases from ~ 15 eV to ~ 5 eV at the inlet and from ~ 6 eV to ~ 2 eV at the target plate by Xe gas injection. $n_e$ once increases by medium Xe gas injection of 50 kPa (plenum pressure) especially near the inlet side and then...
decreases by high Xe gas injection of 100 kPa especially at the target plate. $I_a$ decreases by Xe gas injection and the decrease rate is higher near the corner of the target plate than the inlet. These phenomena suggests the detachment.

Figure 2 shows distributions of $T_e$, $n_e$ and $I_a$ measured by Langmuir probes in H$_2$ and Xe gas injection experiments on the D-module (plenum pressure of H$_2$ is 100 kPa).

Figure 3 shows distributions of $T_e$ and $n_eS$ along magnetic field line direction measured by the three probes between the inlet and the target plate in the same H$_2$ and Xe gas injection experiments, where $S$ is a compensation factor for magnetic flux expansion ($S$ is also cross-sectional area of a magnetic flux tube at the probe position). Without Xe gas, $n_eS$ increases toward the target plate, which suggests ionization is dominant than recombination. With Xe plenum pressure of 50 kPa, $n_eS$ becomes larger, which indicates more ionization due to Xe gas. With more Xe gas of 120 kPa, $n_eS$ becomes smaller and the region where $n_eS$ decreases toward the target plate appears in front of the target plate ($-420 \text{ mm} < Z < -300 \text{ mm}$), which suggests recombination is dominant. Moreover, ionization front (peak of $n_eS$) seems to move to the upstream side with increase of Xe gas. These phenomena is considered to be related to decrease of $T_e$.

4. Summary
$T_e$, $n_e$ and $I_a$ distributions are measured in detachment experiments with H$_2$ and Xe gas injection on the D-module. As Xe gas is increased, $T_e$ and $I_a$ decrease but $n_e$ once increases and then decreases especially near the target plate, which suggests the detachment. And in high Xe gas amount, the region where $n_eS$ decreases toward the target plate appears, which suggests recombination is dominant in front of the target plate.

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References