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Divertor Simulation and Hydrogen Recycling Study Utilizing End Region of the Tandem Mirror GAMMA 10/PDX

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Power and particle handling is one of the most crucial issues for ITER and a future fusion device such as DEMO. It is important to understand fundamental physics of divertor plasma and plasma surface interaction (PSI) including hydrogen recycling for the power and particle control.

In the tandem mirror GAMMA 10/PDX, a new project has been promoted to study divertor physics such as plasma detachment and PSI. As shown in Fig. 1, a divertor simulation experimental module (D-module) has been installed in the end region of GAMMA 10/PDX to make best use of a linear plasma device with plasma confinement. The features of GAMMA 10/PDX for divertor and PSI studies are the following: (1) high ion temperature of the plasma exposed to the D-module (i.e. a few hundreds eV), (2) high magnetic field (0.15~1.5 T), (3) large plasma size (0.1~0.3 m), (4) low background pressure in the vacuum vessel and (5) high controllability of the plasma exposure since plasma heating systems of ECH, ICH and NBI are equipped. It is noted that high ion temperature is suitable to study PSI phenomena such as hydrogen recycling from the viewpoint of divertor simulation for torus plasma. Besides, behavior of neutral atoms in the recycling process can clearly be observed due to the low background pressure in the vacuum vessel. In this paper, a new project of GAMMA 10/PDX is introduced and recent results of divertor simulation and hydrogen recycling are shown.

The D-module consists of a rectangular box (0.5 m square and 0.7 m in length) with an inlet aperture at the front panel and a V-shaped target system inside the box. Tungsten target plates with the thickness of 0.2 mm are attached on a V-shaped base made of Cu. The target size is 0.3 m in width and 0.35 m in length. The length between the front edge of the target and the inlet of the D-module is about 0.3 m. The open-angle of the V-shaped base can remotely be changed from 15 degrees to 80 degrees. The sheath electric heaters are attached on the backside of the Cu base to control the target plate temperature (T_{target}) up to 573 K. Besides, additional hydrogen gas and noble gases of He, Ar, Xe and Kr can be supplied inside the D-module. Measurements with Langmuir probe, spectroscopy, fast camera, ASDEX gauge and so on have been done for the plasma characterization. Moreover, another tungsten target plate with the diameter of 100 mm has been used to study the hydrogen recycling instead of the D-module.

Additional hydrogen gas is supplied into the D-module to achieve plasma detachment. The temperature near the corner of the V-shaped target decreased from ~ 23 eV to ~ 2 eV as the neutral pressure in the D-module increased and a clear density rollover was observed at ~2 Pa. A position of the density maximum moved to upstream of the plasma with increase in the neutral pressure and the density near the corner of the target decreased to detach the plasma from the target. In particular, the density decrease was remarkable near the corner of the V-shaped target due to enhancement of the recycling there. The dependence of the H_α and H_β line intensities on the neutral pressure indicates that molecular activated recombination (MAR) occurred near the corner of the V-shaped target. It is found form a detailed analysis that the triatomic hydrogen molecules play an important role in MAR for the plasma detachment.

Moreover, effects of wall temperature on hydrogen recycling are investigated by using the temperature-controlled V-shaped target. The target was heated to 573 K. The H_α intensity and n_e changed almost linearly with T_{target}. The difference of $I_{H\alpha}$ at 573 K and 383 K is about twice. That of n_e is about 20 %. This indicates that recycling was enhanced by increase in T_{target}. The difference in the change rate between $I_{H\alpha}$ and n_e seems to be attributed to that the density in the D-module is sustained mainly by the plasma flow from the upstream side and production of excited hydrogen atoms is increased by increase in dissociation of the molecules, which may be enhanced by recycling process on the high temperature target. Moreover, additional hydrogen gas was injected into the D-module with the temperature-controlled target. The effect of high target temperature on $I_{H\alpha}$ was significant although that of n_e was little. As the amount of hydrogen gas injection increased, enhancement of hydrogen recycling by high temperature target becomes smaller.

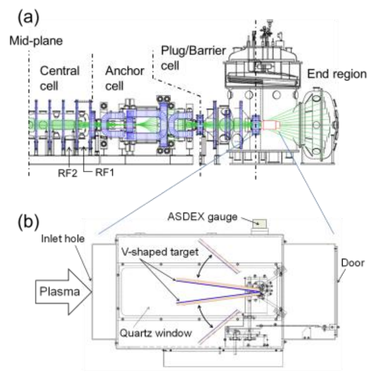

Fig. 1 Schematic views of (a) GAMMA 10/PDX and (b) the D-module.