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Measurements of absolute hydrogen gas pressure in the divertor module in GAMMA 10 and effects on reduction of thermal and particle loads onto the V-shaped target

GAMMA 10ダイバータ模擬実験モジュール内の水素ガスの絶対圧力測定と
V字ターゲットへの熱粒子負荷低減への影響

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To investigate effects of neutral particles on reduction of heat and particle loads onto the divertor target, an ASDEX-type neutral pressure gauge has been installed to a divertor simulation experimental module (D-module) in GAMMA 10/PDX. The sensitivity of the gauge is absolutely calibrated for H_2 gas. Increase in H_2 gas is observed during plasma irradiation to a V-shaped target in D-module.

1. Introduction

Reduction of heat and particle loads onto the plasma-facing components, especially the divertor target, is a crucial issue in a magnetic fusion device. One of the promising techniques is production of radiative and detached plasmas in front of the divertor targets. Although neutrals are expected to play important roles to form these plasmas, fundamental process between ions and neutrals are not clear in detail.

In a large tandem mirror device GAMMA 10/PDX, experiments of plasma irradiation to a V-shaped target have been started to investigate fundamental processes of formation of the radiative and detached plasmas [1]. In this study, a neutral pressure gauge was installed around the V-shaped target to investigate effects of neutrals on reduction of heat and particle loads onto the divertor target.

2. Divertor simulation experimental module and the neutral pressure gauge

A divertor simulation experimental module (D-module) with the V-shaped target was installed at the end-mirror in GAMMA 10/PDX (Fig. 1) [1]. The H plasmas produced in the central-cell region is irradiated to the target. Typical particle flux and ion temperature are up to 1.7×10^{23} m^{-2} and 400 eV, respectively. Hydrogen gas was injected from the entrance of D-module to produce the radiative and detached plasmas.

An ASDEX-type neutral pressure gauge, which can be used with a magnetic field, was installed to the D-module (Fig. 1) [2]. The gauge consists of a filament, control grid, acceleration grid and ion collector. The typical filament current was 10 A and the potential was 70 V. DC potential of 250 and 105 V were applied to the acceleration and the control grid, respectively. An emission current (I_e) and ion collector current (I_{ic}) were measured with the acceleration grid and ion collector, respectively.

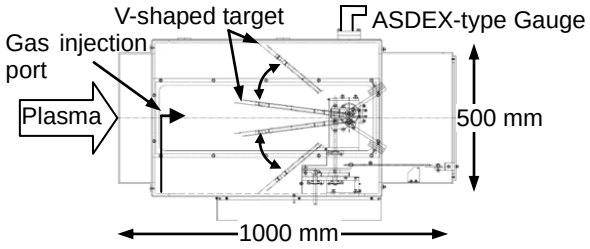

Fig. 1. Schematic view of D-module with the V-shaped target and the ASDEX-type gauge.

3. Evaluation of absolute H_2 gas pressure during plasma irradiation

The sensitivity of the gauge for H_2 gas without the magnetic field and the sensitivity increase by the magnetic field was measured to evaluate absolute H_2 gas pressure in D-module during plasma irradiation.

The sensitivity, absolute H_2 gas pressure against the current ratio $I_{ic}/(I_e-I_{ic})$, was measured with a different chamber from GAMMA 10/PDX without

the magnetic field. The chamber was evacuated to 3 × 10^{-5} Pa, and H_2 gas was introduced. The absolute H_2 gas pressure was measured with a capacitance manometer.

The sensitivity increase by the magnetic field was measured in D-module. Hydrogen gas accumulated in a plenum chamber (490 cm^3) was injected with a piezoelectric valve for 300 ms. The experiment was performed with and without the magnetic field, and the $I_{ic}/(I_e\text{-}I_{ic})$ was compared.

Absolute H_2 gas pressure in D-module during plasma irradiation was evaluated by the conversion equation obtained. Hydrogen gas was injected into D-module by the same method as the calibration experiment, but the duration was extended. After the H_2 gas pressure becomes constant, H plasma was irradiated to the V-shaped target for 200 ms.

3. Evaluation results

The $I_{ic}/(I_e\text{-}I_{ic})$ against the H_2 gas pressure measured with a different chamber from GAMMA 10/PDX is shown in Fig. 2. The sensitivity does not largely change with the emission current, but it gradually decreases with increasing the H_2 gas pressure. As a result, the H_2 gas pressure against the $I_{ic}/(I_e\text{-}I_{ic})$ is fitted by a second-order polynomial function for all the emission current, and the pressure can be expressed as

$$P_{H_2} = 615.5\left(\frac{I_{ic}}{I_e - i_{ic}}\right)^2 + 95.0\frac{I_{ic}}{I_e - I_{ic}}. \quad (1)$$

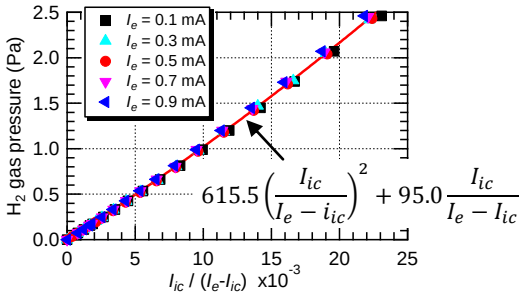

Fig. 2. $I_{ic}/(I_e\text{-}I_{ic})$ against the H_2 gas pressure.

The sensitivity increase with the magnetic field is measured in D-module (Fig. 3). The $I_{ic}/(I_e\text{-}I_{ic})$ increases with the plenum pressure, and it reaches to 11 × 10^{-3} for the plenum pressure of 100 kPa without the magnetic field (Fig. 3(a)). In this case, the gas pressure is evaluated to be 1.2 Pa by Eq. (1). Similar experiments with the magnetic field show that the $I_{ic}/(I_e\text{-}I_{ic})$ reaches to 35 × 10^{-3} for the plenum pressure of 100 kPa (Fig. 3(b)). The sensitivity increase is evaluated to be 3.1 for all the plenum pressure. Hence, the absolute gas pressure in D-module with the magnetic field can be expressed as

$$P_{H_2} = \left(615.5\left(\frac{I_{ic}}{I_e - i_{ic}}\right)^2 + 95.0\frac{I_{ic}}{I_e - I_{ic}}\right)/3.1. \quad (2)$$

Absolute H_2 gas pressure in D-module during plasma irradiation is evaluated by Eq. (2) (Fig. 4). The pressure during the plasma irradiation increases with the plenum pressure. For the higher pressure especially at 100 kPa, the H_2 gas pressure rapidly increases with the plasma irradiation, and it reaches to 8 Pa.

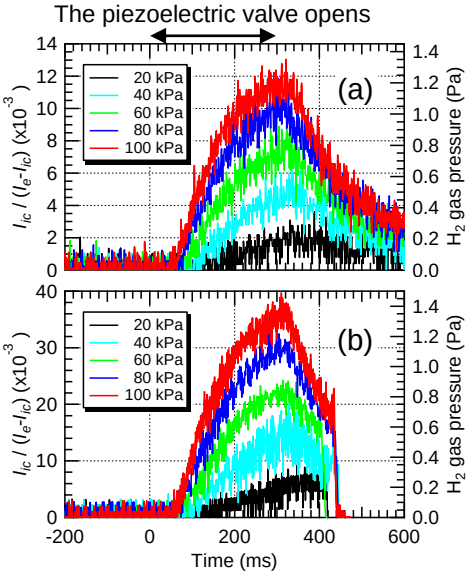

Fig. 3. $I_{ic}/(I_e\text{-}I_{ic})$ and evaluated gas pressure measured in D-module (a) without and (b) with the magnetic field.

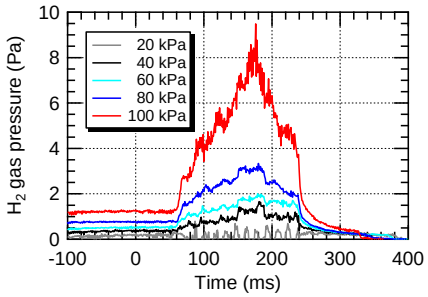

Fig. 4. Absolute H_2 gas pressure in D-module during plasma irradiation.

4. Summary

To measure neutral pressure in D-module during plasma irradiation, the ASDEX-type gauge has been installed. The absolute H_2 gas pressure during plasma irradiation can be evaluated, and it increases up to 8 Pa. Effects of neutrals on the heat and particle loads onto the V-shaped target are discussed in the conference.

References

[1] Y. Nakashima, et al., Trans. Fusion Sci. Technol. **63** No.1T (2013) 100.

[2] G. Haas, et al., J. Nucl. Mater. **121** (1984) 151.