Plasma Detachment in GAMMA 10/PDX Tandem Mirror: Role of Molecule Gases and Target Configuration

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ABSTRACT

- Remarkable progress has been made on the understanding the role of N_2 and H_2 puffing on plasma detachment in divertor simulation experiments using the end-loss region of the tandem mirror device GAMMA 10/PDX. These issues have been experimentally investigated for different target angles using the variable angle V-shaped target system.
- We have newly observed that Molecular Assisted Recombination (MAR) processes are influenced by recycling and compression of additionally supplied gases depending on opening angle of the target plate.

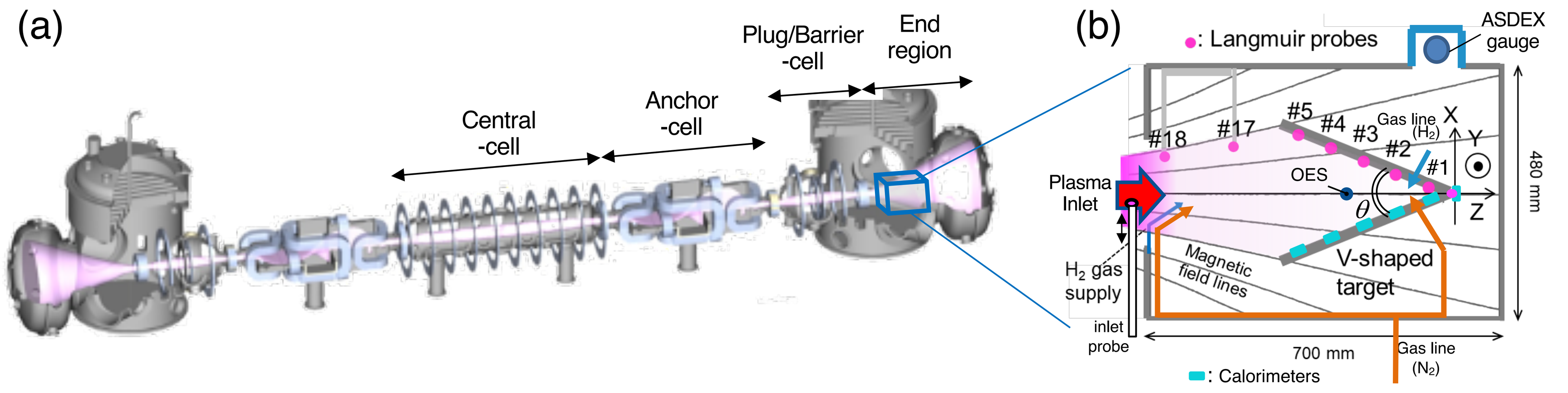
BACKGROUND

- Understandings of the detail mechanism of the recombination process are important for control of divertor plasma detachment.
- The target angle is expected to affect plasma detachment through the change of hydrogen recycling processes, as well as local neutral pressure build-up near the corner of the V-shaped target.
- Interactions between hydrogen recycling and additional gas seeding have a growing importance in optimizing divertor configurations for Demo.

EXPERIMENTAL SETUP

GAMMA 10/PDX tandem mirror & Divertor simulation experimental module

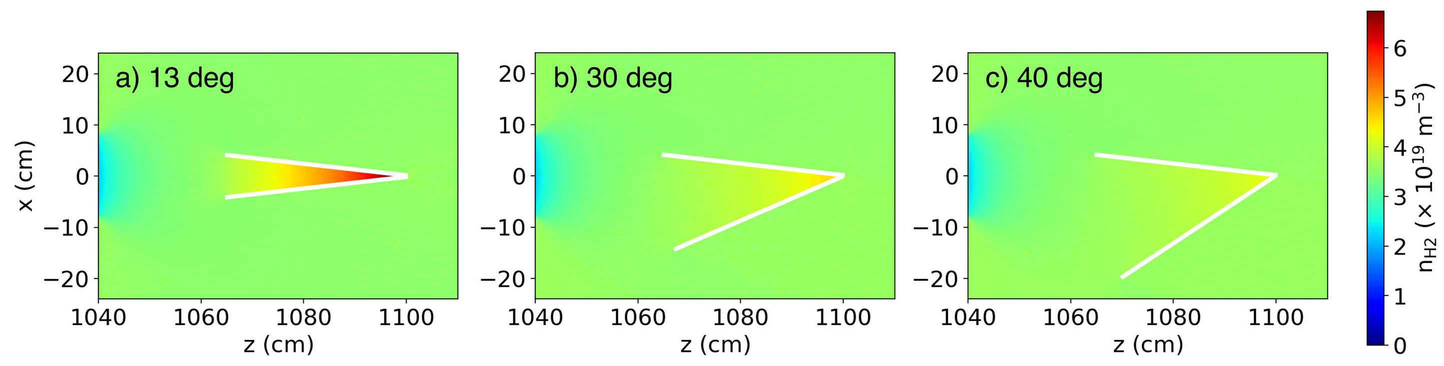
- High temperature end loss plasmas of GAMMA10/PDX provide a practical and effective tool for studying detachment phenomena under equivalent conditions for ITER SOL and divertor plasma with high temperature and strong magnetic field.
- To uncover detailed physics mechanisms responsible for the small angle, experiments of different target angles has been conducted using a variable angle V-shaped target system in the divertor simulation experimental module (D-module) at the end region of GAMMA 10/PDX tandem mirror device [Y. Nakashima: NF 2017, M. Sakamoto: NME 2017, N. Ezumi: NF2019].



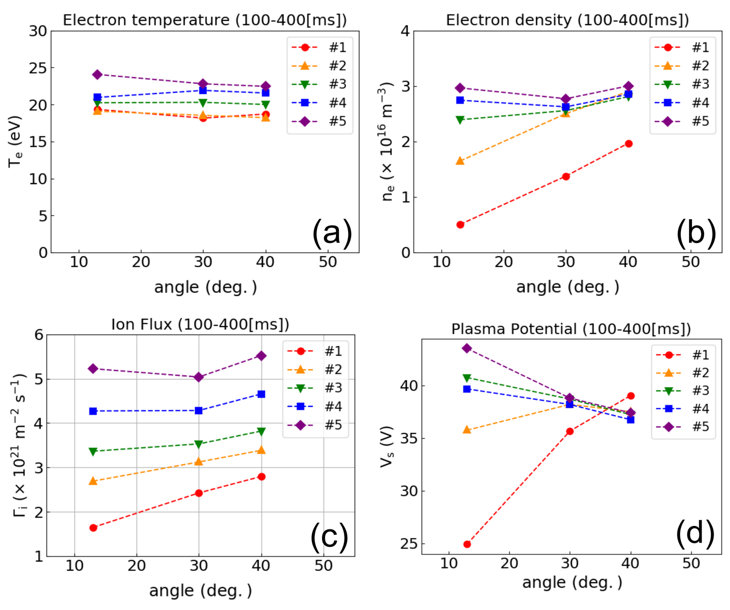
OUTCOME

1. Changes of neutral density profile and plasma parameters due to the angle of V-shaped target without gas seeding

- Spatial profiles of hydrogen molecule density are calculated by 3D neutral particle Monte-Carlo (MC) code "MOLFLOW+" [R. Kersevan: J. Vac. Sci. Tech. A 2009]
- The MC simulation shows the H_2 density near the corner increases with becoming narrow the target angle. Stronger plasma-neutral interactions can be expected in the case of small target angle.

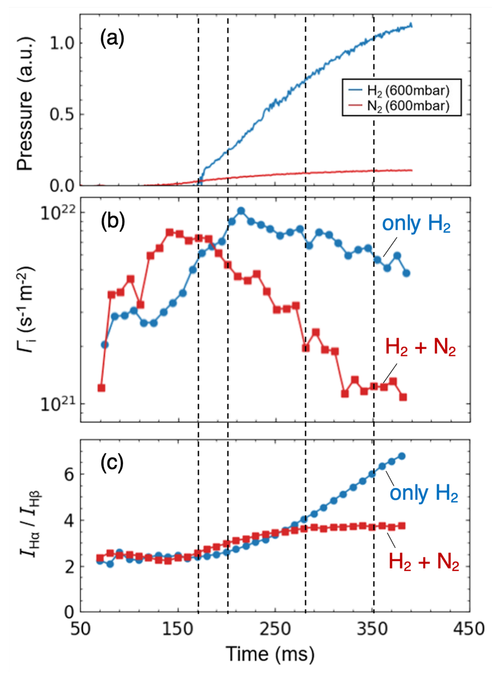


- Experiments varying the angle of the target show ne and ion flux near the target corner decrease with reducing target angle while keeping T_e constant in spite of no additional gas seeding.
- These n_e and Γ_i drop are possibly due to local neutral pressure build-up near the corner of the target caused by hydrogen recycling processes.
- V_s near the target corner decreases significantly.
- Narrowing the target angel might enhance not only raising local neutral pressure but changing the plasma potential profile which lead particle loss.



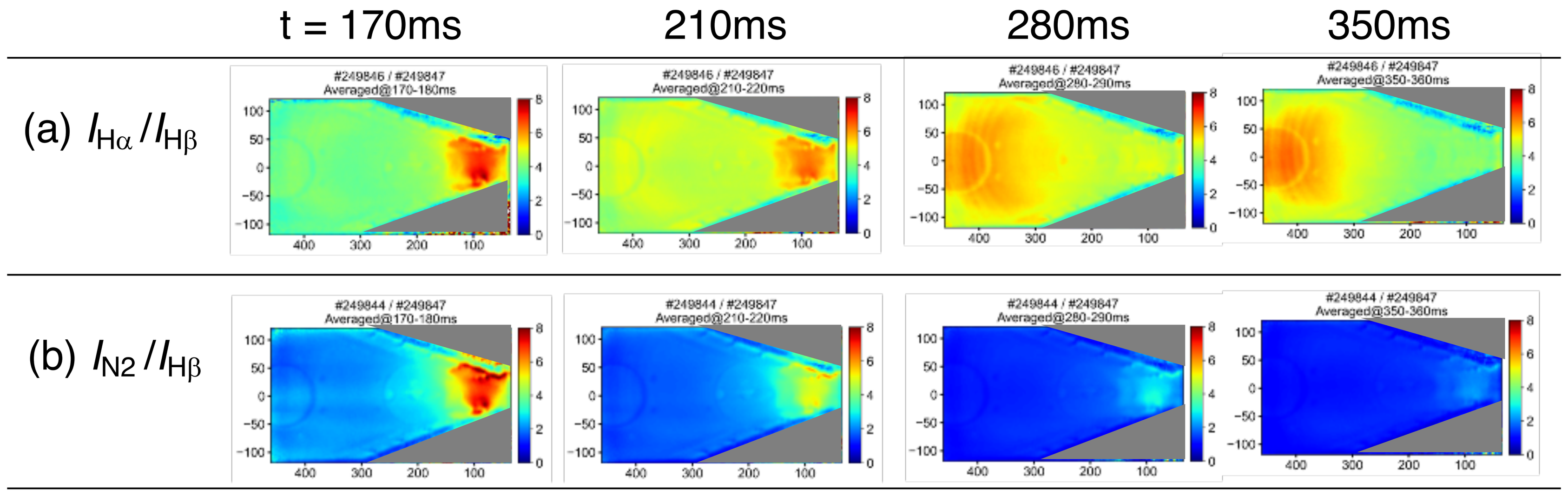
2. Spatial profile of the emissions from N_2 and H-Balmer during combination puffing of N_2 and H_2

- Emission intensity ratio of H_α/H_β during combination gas puffs of N_2 and H_2 becomes smaller than the case of H_2 puff only in spite of drastic ion flux reduction for the case of H_2+N_2 puffs.
- Suppression of the DA process in H-MAR and enhance of Nitrogen induced MAR (N-MAR) [R. Perillo: PPCF 2018] enhanced by the dissociative recombination of NH_x^+ followed by H^+ charge exchange reaction with NH_x.
- Emission intensity of NH radical is increased with gas pressure [N. Ezumi: NF 2019, H. Gamo: PFR 2021]



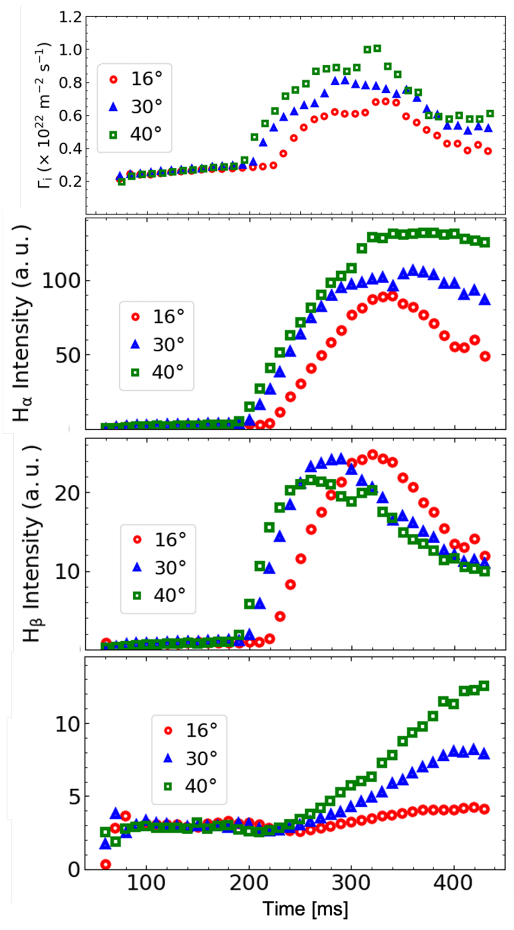
- Spatial profile of the emission intensity ratio (a) $I_{H\alpha}$ / $I_{H\beta}$ and (b) $I_{N2}/I_{H\beta}$ observed by high-speed camera with optical band-path filters.
- $I_{H\alpha}$ / $I_{H\beta}$ becomes smaller near the corner as increasing time.
- $I_{N2}/I_{H\beta}$ ~N_2 density near the corner becomes lower for increasing H_2 gas pressure. It is thought that N_2 is consumed by NH_x production.

t = 170ms, 210ms, 280ms, 350ms



3. Changes of H Balmer lines intensities due to the angle of V-shaped target during H_2 gas puffing

- The intensity ratio decreases as the angle becomes smaller. This suggests that the reaction chains in the MAR process [M. Sakamoto: NME 2017] are changed by the different target angle, even though ion flux reduction for each target angle shows similar tendency.
- The smaller target angle shows the delay of rising timing of H_α and H_β emission intensities as shown in Fig. 4 (b) and (c), respectively.
- These results might be caused by compression of additional H_2 gas at the corner of the V-shaped target.



CONCLUSION

- We have newly observed that MAR processes are influenced by recycling and compression of additionally supplied gases depending on opening angle of the target plate.
- The importance of further understanding of atomic and molecular processes associated with molecular gases and influence of divertor target geometry for improving detached divertor plasma operation.
- N_2 seeding is not only effective at enhancing radiation, but also promoting detachment via N-induced MAR processes.

ACKNOWLEDGEMENTS

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