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Development of a magnetized plasma gun device for ELM-like pulsed plasma irradiation
ELM様パルスプラズマ照射のための磁化プラズマガン装置の開発

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The magnetized coaxial plasma gun (MCPG) device at University of Hyogo for simulation experiments of type-I ELM heat loads has been upgraded to improve the performance. The characteristics of the upgraded MCPG device have been investigated and compared with the previous one. The capacitor bank energy for the power supply of the MCPG was increased from 24.5 kJ to 144 kJ. In the preliminary experiments, the plasmoid with duration of ~0.2 ms, the incident ion energy of ~40 eV, and the surface absorbed energy density of ~2 MJ/m^2 was successfully produced by the present MCPG device at the gun voltage of 6 kV.

1. Introduction

Thermal transient events such as type I edge-localized modes (ELMs) and disruptions remain a major concern to the lifetime of plasma-facing components (PFCs) in ITER. It is predicted that the heat load onto the PFCs during type I ELMs in ITER is 0.2-2MJ/m^2 with pulse length of ~0.1-1ms [1]. Experimental investigations of surface damage characteristics of candidate materials for the PFCs under transient plasma loads are highly required. However, it is difficult to achieve the predicted conditions in present tokamak devices and linear divertor simulators.

We have investigated surface damage of the PFCs under transient heat loads by using a magnetized coaxial plasma gun (MCPG) at University of Hyogo [2]. The stress-relieved W samples were exposed to the repetitive pulsed plasma loads with duration of ~0.5 ms, incident ion energy of ~30 eV, and surface absorbed energy density of ~0.3-0.7 MJ/m^2 [3]. No melting occurred on a W surface exposed to a single plasma pulse of ~0.7 MJ/m^2, while cracks clearly appeared at the edge part of the W surface.

We have recently started to improve the performance of the MCPG in order to investigate melt layer dynamics of a W surface such as vapor cloud formation [4]. In this study, we will show characteristics of the upgraded MCPG device.

2. Experimental setup

Figure 1 shows a schematic view of the upgraded MCPG produced in this study. The MCPG has coaxial electrodes made of stainless steel 304. The inner and outer electrodes are tapered for plasma compression in order to increase the plasma density,

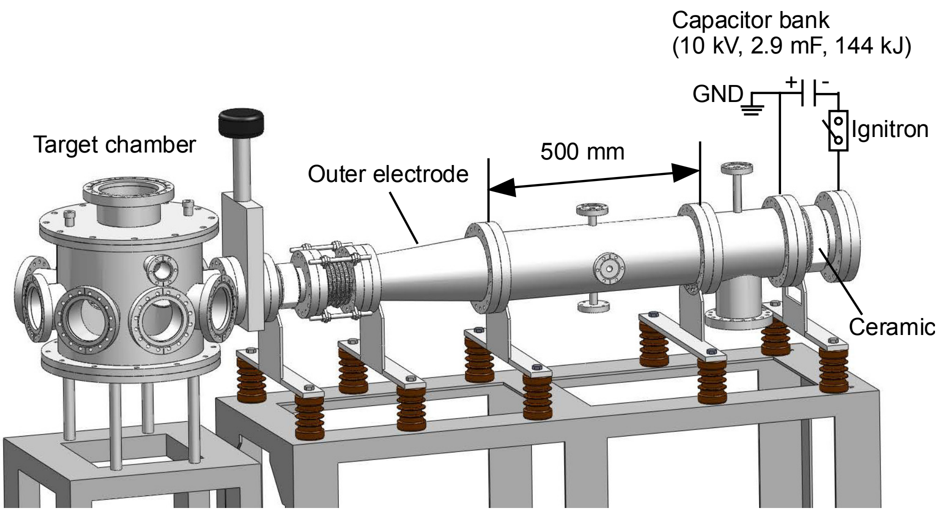

Fig. 1 Magnetized coaxial plasma gun device

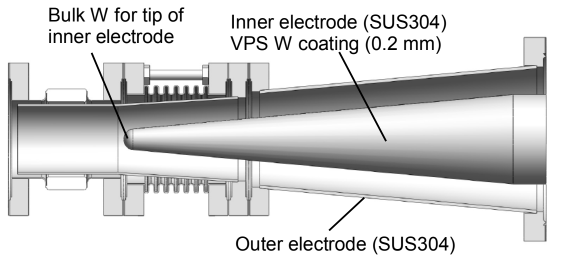

Fig. 2 Inner and outer electrodes in the MCPG device.

since the higher kinetic energy of the plasmoid gives rise to a large energy deposition onto the target. The tip of the inner electrode is made of W to suppress release of impurities from the inner electrode during the discharge (Fig. 2). Two fast gas-puff valves are used to produce neutral gas for the plasma production. The working gas is hydrogen in this study. A bias solenoid coil is installed outside the outer electrode in order to magnetize a plasmoid produced at the formation region. A turbo molecular pump (150 L/s) is connected to the bottom part of the MCPG. The base vacuum pressure is typically 1.0x10^{-7} Torr.

The energy density of ~ 0.7 MJ/m^2 was observed in the former MCPG, in which the capacitor bank (1 mF, 7 kV, 24.5 kJ) was used for the power supply [3]. The energy density has to be increased up to ~ 2 MJ/m^2 in order to achieve droplet splashing of a W surface due to a pulsed plasma bombardment [4]. Then, a high energy density capacitor bank (2.88 mF, 10 kV, 144 kJ) is prepared for the power supply of the upgrade MCPG device. A target chamber is prepared for measurements of dynamics of plasma material interactions due to pulsed plasma irradiation.

3. Experimental results

The surface absorbed energy was measured with the calorimeter by changing the gun voltage and the bias magnetic flux, as shown in Fig. 3. Here, the discharge was unstable when the bias magnetic flux was not applied. It is found that the energy density increases when increasing the gun voltage (i.e., capacitor bank energy). In addition, the peak energy density appears at the bias magnetic flux of ~ 1 mWb. Thus, the energy density can be controlled by the external bias magnetic flux. It is revealed that the higher energy density is observed at the lower gun voltage of 6 kV in the upgraded MCPG. It is expected that the energy density could exceed 2 MJ/m2, corresponding to the threshold of droplet splashing of a W surface due to the pulsed plasma bombardment [4].

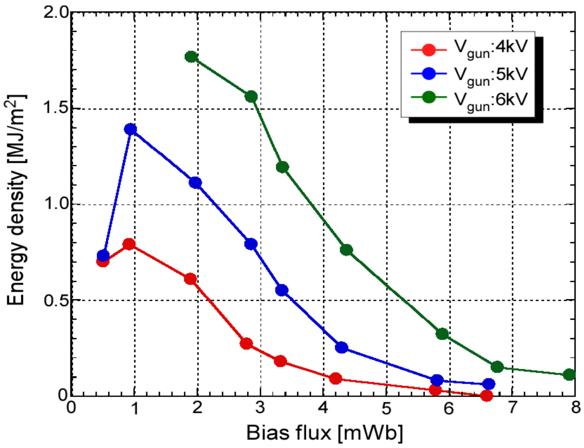

Fig. 3 Dependences of the energy density of the pulsed plasma on the bias flux.

4. Summary

The characteristics of the modified MCPG device were investigated and compared with the previous one. The capacitor bank energy is increased from 24.5 kJ to 144 kJ. In the preliminary experiments, the plasmoid with duration of ~0.2 ms, incident ion energy of ~ 40 eV, and the surface absorbed energy density of ~2 MJ/m^2 was successfully produced by the present MCPG device at the gun voltage of 6 kV.

Acknowledgments

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