20PA-042

Measurements of ELM-Like Pulse Plasma Heat Flux Using a Calorimeter in a Magnetized Plasma Gun

磁化プラズマガンにおけるカロリーメータを用いた
ELM様パルスプラズマの熱流計測

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Measurements of ELM-like pulsed plasma heat load produced by a magnetized coaxial plasma gun were carried out using a calorimeter. The probe tip was made of aluminum (Al) or tungsten (W). It was found that the surface absorbed energy density with the Al tip was smaller than that with the W tip. The generation of Al vapor in front of the probe tip was identified by the Al I emission during the pulsed plasma load. The net heat flux onto the Al tip could be reduced by the Al vapor shielding effect. On the other hand, there was no W I emission in the case of W tip during the plasma irradiation because of its high melting point.

1. Introduction

In magnetically confined fusion device such as ITER, it is important to know lifetime of plasma-facing components (PFCs) under thermal transient events such as type-I ELMs and disruptions [1]. Although mitigation technique of type-I ELMs using pellet injection and resonant magnetic perturbation is going to be developed, it could be difficult to avoid surface damage of the divertor plate due to the pulsed plasma heat loads. Thus, it is important to investigate how the thermal transient events affect the surface damage of the PFCs using simulation facilities such as an electron beam, a laser, and a plasma gun.

We have studied surface damage of tungsten materials under pulsed plasma heat loads using a magnetized coaxial plasma gun (MCPG) at Univ. of Hyogo [2]. Heat flux density of the pulsed plasma load produced by the MCPG device is a key parameter for determining the material erosion. In this study, measurements of the surface absorbed energy density were carried out using a calorimeter. The observed absorbed energy density was discussed with the vapor shielding phenomena which affects the heat transfer process from the pulsed plasma load to the material surface.

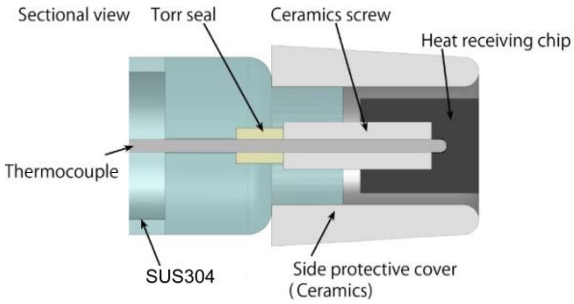

Fig. 1. Schematic view of the calorimeter

2. Experimental Setup

In the present study, the gun voltage was 5.5 kV in the MCPG device. The discharge gas was helium (He). Figure 1 shows the schematic view of the calorimeter developed in this study. The heat receiving probe tip of the calorimeter is made of cylindrical tungsten (W) or aluminum (Al), whose length is 10 mm, and diameter is 8 mm. The probe tip is equipped with a K-type thermo-couple for the measurement of temperature increase during the pulsed plasma load. The measurement location of the temperature is 3 mm behind the tip surface. In addition, the probe tip is thermally and electrically isolated using a ceramics screw to fix the probe tip. The side of the probe tip is covered with a ceramics part in order to suppress the plasma heat flow onto the side part of the probe tip.

The surface absorbed energy density was calculated using the temperature increase during the pulsed plasma by the following equation.

$$E = \frac{m}{s}\int_{T_{MIN}}^{T_{MAX}} c(T)dT \quad [\mathrm{J/m^2}] \qquad (1)$$

Here, E, m, S, $T_{\max}$, $T_{\min}$, c are the surface absorbed energy density, the mass of the probe tip, the surface area of the probe tip, the maximum temperature after the pulsed plasma load, the temperature before the pulsed plasma load, and the specific heat, respectively. The energy density estimated by eq. (1) was validated by comparing a commercially available 3D heat conduction solver of ANSYS software [3].

3. Experimental Results

Figure 2 shows the surface absorbed energy density when changing the capacitor bank energy. At the higher pulsed plasma energy, the surface absorbed energy density with the W probe tip was larger than that with the Al probe tip. Measurements of the plasma optical emission during the pulsed plasma irradiation were performed in order to investigate the reason of the difference of the surface absorbed energy density between two kinds of probe tip. Figure 3 shows time evolutions of the line-averaged electron density measured by a He-Ne interferometer, the He II (468.58 nm) emission, and the Al I (394.40 nm) emission, respectively. Here, the optical emission was measured with and without the calorimeter. It was found that the Al I emission clearly appeared with the Al calorimeter. On the other hand, no W I (400.98 nm) emission was observed during the pulsed plasma load onto the W calorimeter. Thus, it could be considered that the reduction of the surface absorbed energy density originated from the vapor shielding effect [4] of the Al vapor in front of the probe tip.

The surface temperature of the probe tip during the pulsed heat load of 0.38 $\mathrm{MJm^{-2}}$ with the pulse length of 0.18 ms was calculated using the ANSYS software. The peak surface temperature on the W tip is 1594 K, which is lower than the melting point of W. On the other hand, it is 1464 K in the case of the Al tip, which is higher than the melting point of Al. The boiling point of Al at 1atm is 2740 K, however, it could be lower in the present experiment because of the low pressure. Thus, the vapor layer could appear in front of the probe tip during the pulsed plasma irradiation.

4. Summary

The measurements of the surface absorbed energy density of the pulsed plasma produced by the MCPG device were carried out using the calorimeter. The optical emission from the Al probe tip suggested that the surface energy density was reduced by the Al vapor shielding effect. On the other hand, there was no vapor shielding effect on the W probe tip because of its high melting point.

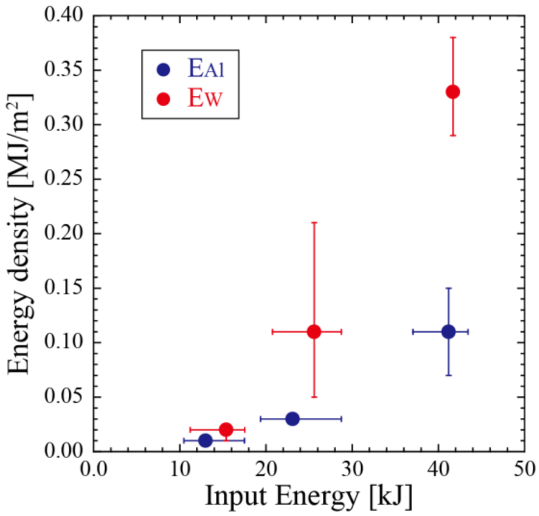

Fig. 2. Surface absorbed energy density measured by the calorimeter with Al and W probe tips.

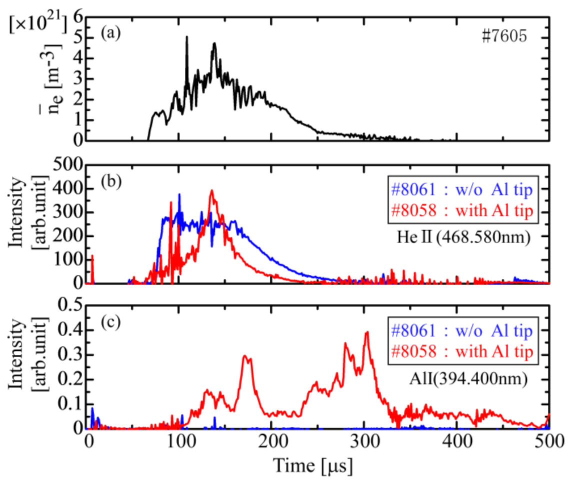

Fig. 3. Time evolutions of the line-averaged electron densy, the He II emission, and the Al I emission with and without the Al calorimeter.

Acknowledgments

This work was supported by Grant-in-Aid for Scientific Research (C) 26400535.

References

[1] G. Federici et al.:Plasma Phys. Control. Fusion **45** (2003) 1523.

[2] I. Sakuma, Y. Kikuchi, Y. Kitagawa, et al.: *accepted for publication in* J. Nucl. Mater.

[3] http://www.ansys.com/

[4] A. Hassanein, Fusion Eng. Des. **60** (2002) 527.