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Spectroscopic Studies of Plasma-Material Interaction under ELM-like Pulse Plasma Loads

ELM様パルスプラズマ照射時におけるプラズマ・材料相互作用の分光計測

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Spectroscopic studies of plasma-material interaction under ELM-like pulse plasma loads produced by a magnetized coaxial plasma gun were carried out in order to clarify vapor shielding physics. The interaction between a thin aluminum (Al) foil and incoming helium (He) pulsed plasma load was investigated. It was found that the Al II emission was excited with a delay time of ~50 μs after the He II emission appeared. It was also observed the Al II emission expanded to the upstream direction from the material surface. The result suggests the dynamic behavior of phase change of the Al foil due to the pulsed plasma irradiation.

1. Introduction

Material erosion due to transient events such as type- I ELMs and disruptions is one of the crucial issues for the lifetime of the plasma-facing components in future magnetically confined fusion devices [1]. Tungsten (W) is used for the divertor plate in ITER because of its high melting point, and low tritium retention. However, it is considered that surface modifications of W such as melting, crack formation, and arcing could appear. On the other hand, vapor shielding is considered to be important phenomena for energy transfer from the pulsed plasma load to the divertor material [2]. The vapor layer between the plasma and the material could play a role as a thermal barrier, so that net heat flux in front of the material could be reduced.

Recently, we have performed simulation experiments of vapor shielding effects using double plasma gun device [3]. The surface absorbed energy measured by a calorimeter was successfully reduced by using a thin aluminum (Al) foil as an ablator material. In this study, spectroscopic measurements were carried out in order to clarify the interaction between the incoming pulsed plasma and the vapor/plasma layer.

2. Experimental Setup

A magnetized coaxial plasma gun (MCPG) was used to produce a pulsed plasma heat load. A capacitor bank (2.88 mF, 10 kV, 144 kJ) was used for the formation bank of the MCPG. The gun voltage was 5.5 kV in this study. Helium (He) was used as the discharge gas. The MCPG was connected to a target chamber, as shown in Fig. 1(a).

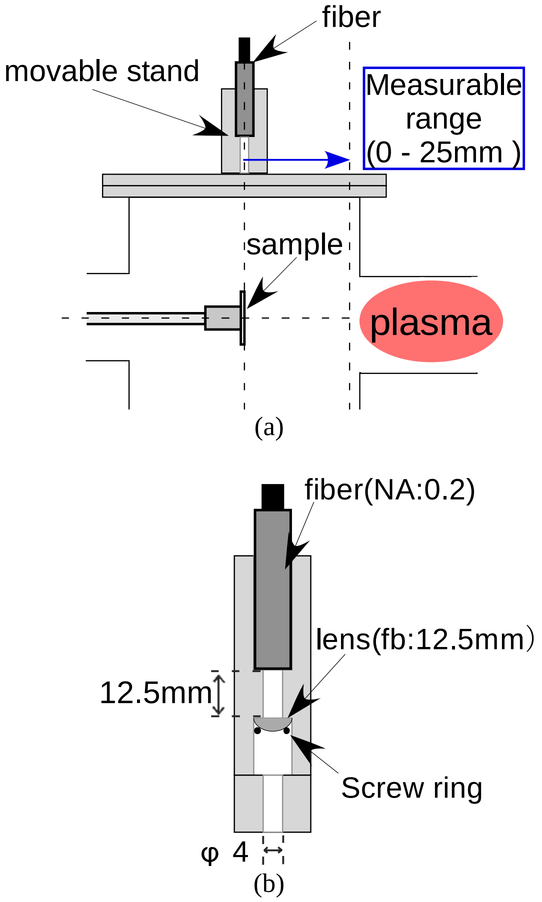

Fig. 1. Schematic view of (a) the target chamber, (b) a light collecting system

An Al foil with a thickness of 11 µm was used as a target material. Figure 1 shows the schematic view of the target chamber, where the configuration of spectroscopic measurements was also shown. An ion Doppler spectrometer (IDS) was used for measurements of optical emission from the plasma. The IDS system consists of 1 m-spectrometer (model MC-100N, Ritsu Ouyou Kougaku Co. Ltd.) and a compact 16 channel photomultiplier tube (PMT) detector [4]. The wavelength resolution of IDS is 0.018 nm. A light collection system consists of a diaphragm of 4 mm, a collimating lens and an optical fiber, as shown in Fig. 1(b). The light collection system can be moved along the plasmoid traveling direction. In this study, the optical emission of He II (468.58 nm) and Al II (559.33 nm) was measured by the IDS. The ion temperature can be evaluated from the Doppler broadening of He II and Al II emission.

3. Experimental Results

Figure 2 shows time evolutions of the optical emission intensities of He II and Al II. Here, the optical emission of He II was measured with another spectrometer at the same shot. It was observed that the Al II emission was excited with a delay time of ~50 µs after the He II emission appeared. It is considered that the delay time originates from the phase change of the Al foil due to the temperature increase during the pulsed plasma heat load. The ionization of Al due to the incoming He plasma was clearly observed.

The spatial structure of Al II emission was observed by changing the position of the light collecting system. Figure 3 shows the profile of the time integrated intensity of the Al II emission along the plasma traveling direction. Here, the horizontal axis corresponds to the distance from the material surface. Since the position of the light collecting system was moved at each plasma shot, the time integrated Al II emission was normalized by that of He II emission at the same shot. As the result, it was observed that the Al plasma expanded to the upstream at around 25 mm from the material surface.

Finally, the ion temperatures of the incoming He plasma and the Al plasma were estimated from the Doppler broadening of He II and Al II emission. As the result, the Al ion temperature was ~40 eV, that was almost same as the He ion temperature. It could be considered that there was thermal relaxation process between the Al ion and the incoming He ion.

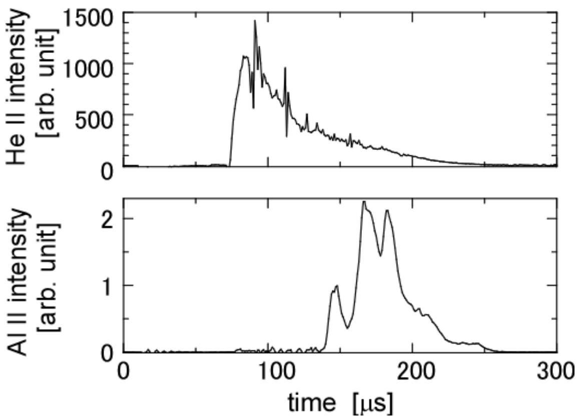

Fig. 2. Time evolutions of the optical emission of He II and Al II.

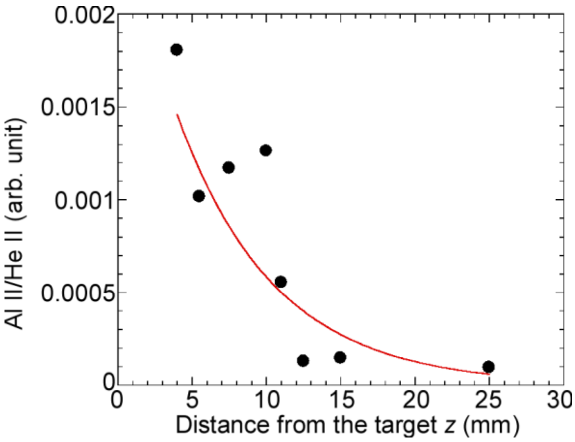

Fig. 3. Profile of the Al II emission intensity normalized by that of He II.

4. Summary

We have performed the spectroscopic measurements of the optical emission from the plasma produced by the interaction between the Al foil and the He pulsed plasma in the MCPG device. It was found that the Al II emission was excited with a delay time of ~50 µs after the He II emission appeared. It was also observed the Al II emission expanded to the upstream direction from the material surface. The result suggests the dynamic behavior of phase change of the Al foil due to the pulsed plasma irradiation.

Acknowledgments

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