# 20PA-038

# Experimental investigation of vapor shielding effects on fusion reactor materials using the double plasma gun device
ダブルプラズマガン装置における核融合炉壁材料を用いた
蒸気遮蔽効果の検証実験

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Vapor shielding effect was investigated using ELM-like pulsed plasma loads produced by the double plasma gun device. The surface absorbed energy density of the pulsed plasma was 0.4 $MJm^{-2}$ and the pulse duration is ~5 ms. In this study, an aluminum (Al) coated tungsten (W) sample was used in order to produce the Al vapor layer. Measurements of the Al I emission and the back surface temperature were performed to clarify the heat transfer from the pulsed plasma to the material. As the result, the vapor shielding effect was successfully identified from the reduction of the temperature increase due to the pulsed plasma irradiation.

## 1. Introduction

It is considered that thermal transient event such as type I edge localized modes (ELMs) could limit the lifetime of plasma-facing components (PFCs) in ITER. On the other hand, surface melting and evaporation during the transient events could generate a vapor cloud layer in front of the target material [1]. Then, the subsequent erosion could be reduced by the interaction between incident plasma particles and the vapor layer, because the net energy flux to the original target surface is significantly reduced due to radiation cooling [2]. Simulation experiments using a pulsed plasma load are needed to validate the prediction by the numerical simulation [3]. The vapor shielding effects have been experimentally identified in simulation experiments using a pulse plasma gun (MK-200) [4], a quasi-steady state plasma accelerator (QSPA) device [5], and the double plasma gun device at Univ. of Hyogo [6].

In this study, an aluminum (Al) coated tungsten (W) sample was used for a target material because of the following two objectives. The melting and vaporization points of Al are 933 K and 2792 K. Thus, it is considered that vapor shielding physics studies with Al can be performed with relatively low energy pulsed heat loads. Secondary, Al is one of the candidate materials to simulate beryllium (Be) in laboratory experiments [7], because Be is toxic material. In particular, it is considered that the deposition of Be eroded from the first wall could result in the formation of Be layer on the W diveror plate in ITER [8]. Thus, the use of Al coated W material is of interest for both clarification of vapor shielding physics and surface modification of the divertor plate.

## 2. Experimental setup

We have studied simulation experiments of ELM-like pulsed plasma load using a magnetized coaxial plasma gun (MCPG) [9]. In this study, an additional 2nd capacitor bank (0.7 kV, 280 mF, 68.5 kJ) was installed to the power supply of the gun discharge in order to produce a pulsed plasma load with a long pulse length. After the initiation of the plasma by applying the 1st bank (2 kV, 2.88 mF, 5.76 kJ), the plasma pulse was maintained by the 2nd bank. As the result, the surface absorbed energy density measured by a calorimeter and the pulse duration of the pulsed plasma were typically ~0.4 $MJm^{-2}$ and ~5 ms, respectively. Helium (He) was used as a discharge gas in this study.

The Al coated W samples were prepared by a vacuum PVD (physical vapor deposition) method in NAGDIS-II. The thickness of deposited Al layer and the W bulk layer are ~1 μm and 50 μm, respectively. The surface temperature of the Al coated W sample during the pulsed heat load of 0.4 $MJm^{-2}$ with a pulse length of 5 ms was estimated by solving one dimensional heat conduction equation. It suggests that the peak surface temperature reaches ~2300 K, so that the pulsed plasma load could cause vaporization of the sample.

To investigate the vapor shielding effect, the back surface temperature of the Al coated W sample was measured by a high-speed pyrometer.

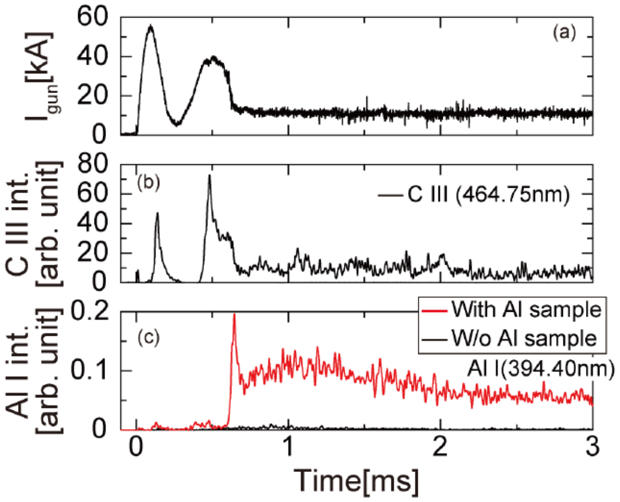


**Fig. 1** The time evolutions of a MCPG discharge. (a): The plasma discharge current, (b): C III (464.75nm)emission and (c): Al I (394.40 nm) emission with and without Al sample

The pyrometer can detect temperature range higher than 1000 K and its time resolution is ~5 μs.

## 3. Experimental result

Figure 1 shows time evolutions of the gun discharge current, the C III emission (464.75 nm), and the Al I emission (349.40 nm) with and without the sample. Here, these waveforms were measured at the same discharge (#8083) except the Al I emission without the sample. Firstly, the C III emission appeared due to the plasma generation, and then the Al I emission was excited with a delay time, as shown in Fig. 1. Here, the same emission line without the Al deposited sample was almost same as the background noise level. Thus, it can be concluded that an Al ablated vapor layer was generated during the plasma irradiation.

Figure 2 shows the peak temperature at the back surface by each plasma shot. Here, the temperature of W sample without the Al layer is ~2200 K. It was found that the temperature increase due to the plasma irradiation was decreased by ~30% in comparison with that of W sample without the Al layer. The temperature gradually increased up to that of W sample without the Al layer. After the several plasma shots, the Al layer on the sample disappeared. As shown in Fig. 1, the Al I emission was clearly observed during the plasma irradiation. Thus, the reduction of the temperature increase of the Al coated W sample during the pulsed plasma load originated from the interaction between the Al vapor/plasma and the incoming He pulsed plasma.

## 4. Conclusion

The heat transfer process from the pulsed plasma load to the Al coated W material was investigated based on measurements of the plasma optical emission and the back surface temperature. The reduction of the temperature increase of the Al coated W sample during the pulsed plasma load was clearly observed. The observed phenomena cannot be explained by the latent heat of Al layer due the phase change. As the result, it can be concluded that the energy transmission factor from the pulsed heat load to the W surface was decreased due to the vapor shielding effect of the Al layer. Moreover, the thin Al layer of ~1 μm is enough to trigger the vapor shielding effect. Therefore, the Be layer deposition on the W divertor plate could modify the heat deposition from thermal transient events in ITER.

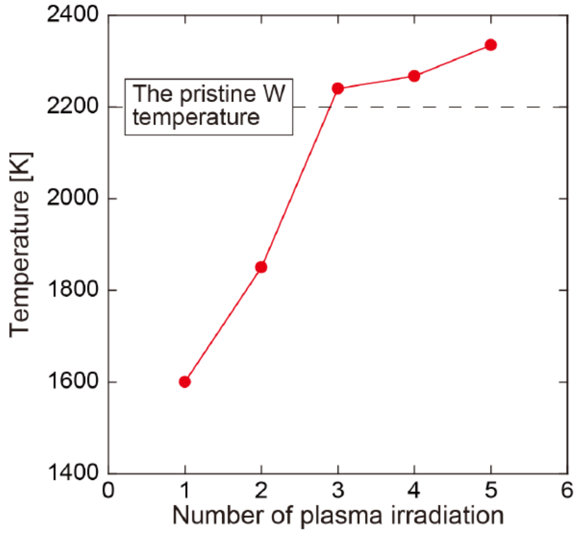


**Fig. 2** The back surface temperature depending on the number of the plasma irradiation


## Acknowledgments

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