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Material Dependence on Plasma Shielding Induced by Laser Ablation
レーザーアブレーションを用いたPlasma Shieldingの材料依存性

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Plasma shielding is to study the effect of ablated plasma or the intentionally created plasma plume on the first wall by absorbing next incoming plasma energy. Two laser ablation plasma (n~10^{12}/cm^3, T_e~1eV) are created and are crossed each other in our experimental platform. 10~60% of the incoming plasma particles change the direction. The ratios are different with the plasma material. By observing the material dependence of colliding effects, the relation to plasma shielding is discussed.

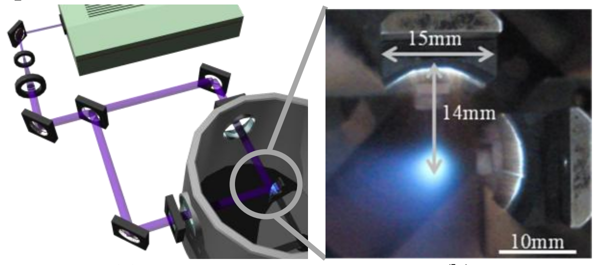
1. Introduction

In nuclear fusion research, it is one of the important themes to study the damage on plasma facing components (PFC). For example, expected heat loads are 10 to 100 MW/m^2 at magnetic fusion energy (MFE) divertor and 10^9 W/cm^2 or higher at inertial fusion energy (IFE) first walls at plasma densities 10^{19} /m^3 or higher and temperature 1 eV to keV or even to MeV. However active functions are proposed to protect the walls like vapor shielding [1] and plasma shielding effects. Our intention is to shed light on this effect. For this purpose, the behavior of ablated plasma should be studied. For example in IFE chamber, the stagnation of ablated plasma plumes affects next laser irradiation. To solve these problems, it is necessary to study how the ablated plasma from IFE chamber wall behaves with the cylindrical structure.

In our experiments, the direction of the collided plumes changed when plasma plumes made by laser ablation are crossed each other. As the material of plasma plume, several target materials are used such as Carbon and Tungsten.

2. Experimental Setup

Plasma shielding is studied using the experimental set up "LEAF-CAP" (Laboratory Experiments on Aerosol Formation by Colliding Ablation Plumes) [2]. Fig.1 (a) shows the set up, a third harmonic beam of YAG laser (6ns, 10Hz) is optically split into equal-power, and each beams are line-focused (~0.1mm by ~1cm), then these radiate two cone-cave targets at room temperature in a vacuum chamber (~10^{-3} Pa). Carbon, Aluminum, Copper, Molybdenum and Tungsten are set as the target. The plasma plumes ablated on the cone-cave targets cross each other on the 14 mm point from the surfaces (Fig.1 (b)). The line-focused laser energy is 10J/cm^2/pulse, at this energy the plasma density is ~10^{12}/cm^3 and the temperature is ~1eV [3].



(a) (b)
Fig.1. Experimental set up "LEAF-CAP"

A quartz thickness monitor is set to measure the number of plasma particles at (i) Front or (ii) Side (45^o) in Fig.2. The depositions at each place are compared with and without shield plasma (which ablated by the perpendicular laser to the monitor at (i) Front).

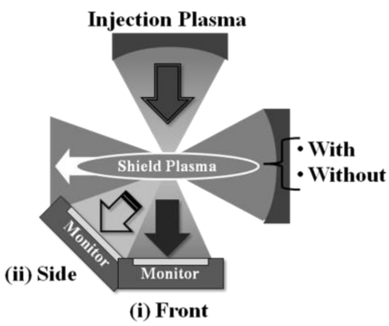


Fig.2. The place of quartz thickness monitor

3. Results and Discussion

3.1 *Results of the quartz thickness monitor*

Fig. 3 shows the result of the quartz thickness monitor at each place with and without shield plasma in case of Carbon targets. Without shield plasma, the coat speed at Side is 0.21 Å/sec and it is 1.4% of total. With shield plasma, the side is 13 times and the front is 0.41 times than the without case, and the side is 31% of total. Taking deposition from two directions into consideration, the coat speeds in case with shield plasma at side are in half. These results suggest that plasma collides and the ratio of side increases by 30 points.

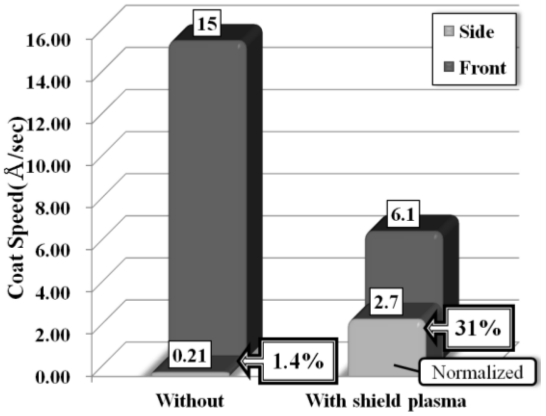
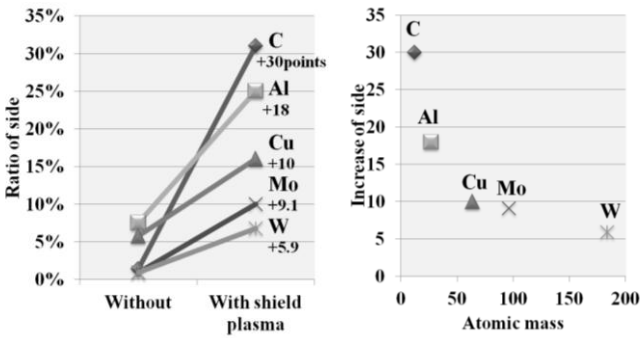


Fig.3. Results of quartz thickness monitor (Carbon)

3.2 *Material dependence*

The above tendency is also observed in cases of other materials. However the ratios of side are different, as shown in Fig.4 (a). In addition, Fig.4 (b) shows that the ratios are depend on the atomic mass, namely more plasma is changed the line in the smaller atomic mass.



(a) (b)

Fig.4. Material dependence of shielding

3.3 *Collision parameter*

To consider the difference of collision effects in materials, the Collision parameter is provided in standing on theoretical equation. The rate of collision is a function of ion charge, mass (m) and velocity (u) in the simulation of plasma collision [4], and we define the collision parameter as:

$$\text{Collision parameter} = \frac{e_\alpha}{m^2 u^3} \qquad (1)$$

In equation (1), e_α is the divided value with ion charge [5]. Fig.5 shows that the collision parameter is linearly correlated with the increase of side in our experiment.

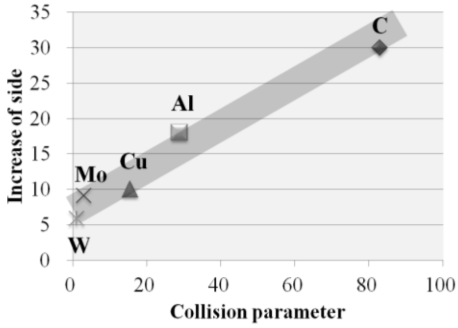


Fig.5. Collision parameter to increase of side

4. Conclusion

Through the intersection of two plasma plumes, 10~60% of the particles changes the direction.

The increases of the side vary with the material. Our results show that plasma shielding may be effective in the smaller atomic mass plasmas.

Introducing the collision parameter in standing, one can observe a linear correlation with the experimental data. This parameter can be treated as the degree of plasma collision and the plasma shielding.

Acknowledgments

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