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Generation of Microwave Plasma Jet and Analysis on Launcher Nozzle at Atmospheric Pressure in Airtight Chamber

気密容器内での大気圧マイクロ波プラズマ・ジェット生成とそのためのランチャー解析

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Launcher nozzle for microwave plasma jet at atmospheric pressure has been developing by improving TIAGO nozzle which has no air-tight configuration. Electromagnetic analysis code, PHOTON Series -‘Wave jω’ gives field distribution around the nozzle which helps the optimization of launcher nozzle.
Generation of microwave plasma jet at atmospheric pressure in airtight chamber would make the PWI experiment possible. Generation of microwave plasma jet at atmospheric pressure in airtight chamber and PWI experiment have been done under the electromagnetic analysis.

1. Introduction

Atmospheric-pressure plasmas have attracted much interest recently for applications in materials synthesis, surface treatment, etching, film deposition, medical treatment, environmental application and many more. They may also have great potentiality for the very high heat-flux plasma beam intended for fundamental research on plasma-wall interactions (PWI) in next-fusion devices, such as ITER (International Thermonuclear Experimental Reactor).

In recent years, the production of microwave plasma jets at atmospheric pressure using the recently developed TIAGO nozzle[1, 2] become very popular due to its simplicity, easy ignition, unnecessity of airtight chamber and sustainment of discharge at the open air having a gas flow function.

But TIAGO system has no air-tight structure for atmospheric-pressure. Recently, launcher nozzle [3] for PWI experiment using airtight chamber has been developed. Launcher nozzle has a structure which connects the waveguide with the airtight chamber.

Here, we use an electromagnetic analysis code for the launcher nozzle. The evaluation and optimization have been made. We also tried to generate high heat flux plasma jet in the airtight chamber for PWI studies.

2. Experimental Set-up

Generation system of microwave plasma jet at atmospheric-pressure with TIAGO nozzle strengthens the microwave electric field on the top of nozzle which has a tapered conical structure. Also, standing wave peak generated with a short plunger along the waveguide is adjusted in position so that the loop of standing electric field is located at the nozzle. Electromagnetic configuration in the waveguide is TE_{10}mode. Launcher nozzle is developed by changing the TIAGO nozzle by adding a airtight function as shown in Fig.1. The chamber is set perpendicular to the waveguide.

Details of Launcher nozzle and microwave circuit are shown in Fig.1.

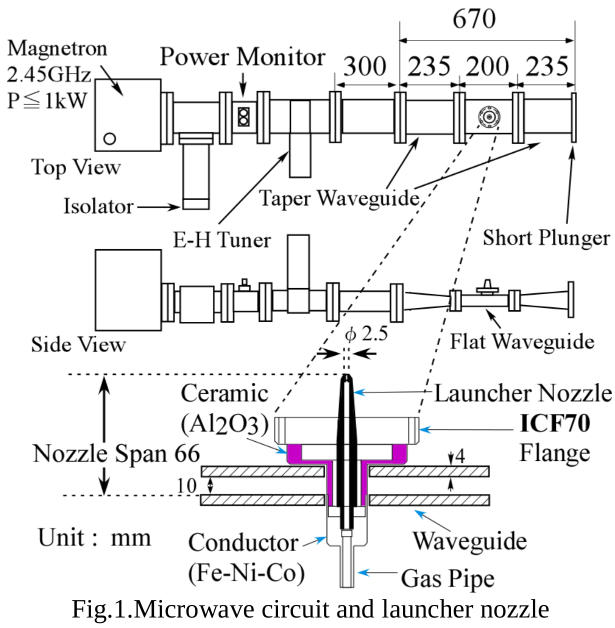

Fig.1.Microwave circuit and launcher nozzle

3. Numerical Analysis

PHOTO Series–‘Wave jω’ of PHOTON Co has

been used for the electromagnetic analysis. The programme employed is three-dimensional frequency response code by finite element method. It gives electric field distribution over the free space by taking account of boundary conditions.

As boundary conditions, we have either a symmetric or nonreflective boundary conditions depending on the boundary property. The wavelength in free space is λ = 122.4mm so that the mesh size is set < $\lambda/6$ = 20.40mm. Wavelength in the waveguide (TE_{10} mode) is $\lambda_g/4$ =36.94mm. The field at the waveguide entrance is put E_y = 1V/m, corresponding to a reference electric field. Deployment models and the mesh are shown in Fig.2.

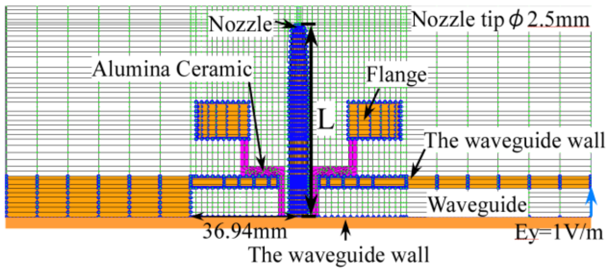

Fig.2.Model configuration with mesh for numerical analysis

4. Summary

4-1.*Analysis on Launcher nozzle*

The numerical analysis gives the electric field distribution along the nozzle height. Basic nozzle length is 66mm (H=66mm).

The distance *d* between the nozzle tip and the first node of electric field distribution is less than $\lambda/4$. It means that the terminal load in the sense of distributed transmission line would be capacitive due to the radiative electric field. The distance between the neighboring loops or node is approximately a half of free space wavelengths.

4-2 *PWI Experiment*

PWI experiment has been done in the airtight chamber, where the working gas is He. Before generating a plasma, we will put to inject gas in turn He $\rightarrow$ N_2 $\rightarrow$ He in order to purge the oxygen for preventing the formation of tungsten trioxide. The W surface temperature, its floating potential and the gas pressure in airtight chamber have been followed for 5 min. Temperature has been measured by radiation thermometer. Emissivity of radiation thermometer is set 0.43 at the wavelength of 0.9μm. The time traces of these quantities are shown in Fig.4.

The temperature approaches to near 1800K. Even such a high surface temperature of tungsten material does not give any color change, meaning the suppression of WO_3 formation since it has a yellow color.

Reading of crystal gauge is increased when the microwave power turns off. We thought that the air comes into the airtight chamber when the microwave power turns off. Because He gas is expanded by the plasma heat, it shrinks by the microwave turn off, and the air comes into the airtight chamber at this instance.

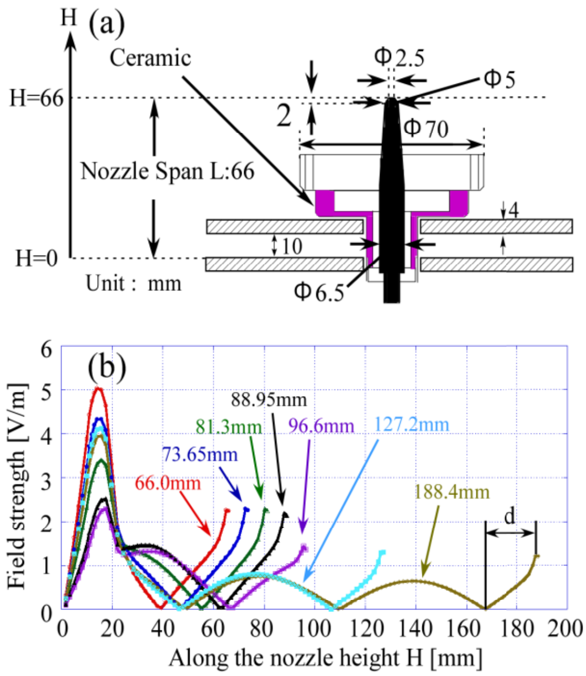

Fig.3. (a) Launcher nozzle set on the waveguide
(b) Electric field distribution along the nozzle

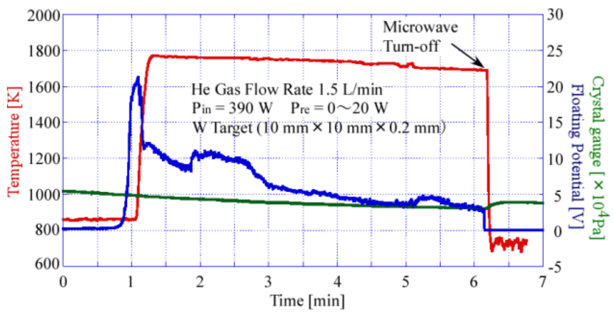

Fig.4. Temporal evolutions of W surface temperature, the floating potential and the gas pressure in the chamber. He gas flow rate is 1.5L/min, and microwave power is 390W. Irradiation time is about 5 minutes.

References

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