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Plasma movement mechanism in pseudo-continuous meter-scale atmospheric-pressure line plasma

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1. Introduction

Atmospheric pressure plasmas (APP) have been given much attention because of its cost benefit and a variety of possibilities for industrial applications such as large area processing. So far, we have developed a meter-scale 2.45 GHz microwave line plasma source which consists of a loop-structure waveguide antenna. Spatio-temporal behavior of the plasma was investigated by a high speed camera and pseudo-continuous line plasma over 0.8 m in length was realized by movement of small plasmas along the long line slot in the direction of the microwave power propagation. In emission intensity profile along the slot from a single plasma, asymmetric structure and higher emission intensity was observed in the vicinity of the plasma edge of the microwave downstream side, suggesting the plasma movement was induced by the asymmetric ionization rate[1]. In this study, the discharge mechanism of this plasma is investigated by narrower gap antenna and three-dimensional electromagnetic field simulations.

2. Experimental

In the experiment, a pulse-modulated microwave source (pulse-frequency: 20 kHz, duty cycle: 30 %, peak power: 2.1 kW) was connected to the loop waveguide system. A long slot (0.9 m in length, 0.3 mm in width,) was cut in a part of the loop waveguide. A section of the loop waveguide that included the slot was vacuum-sealed by two airtight windows and was connected to a vacuum chamber. The chamber as well as the vacuum-sealed part of the waveguide was evacuated by a rotary pump. After the evacuation, the chamber and the sealed waveguide were filled with helium or argon gas at a flow rate of 5000 sccm through small 33 holes on the waveguide. The spatial distribution of the plasma was observed by a digital still camera and a high speed camera. Figure 1 shows schematic of the model geometry of the simulation. A long slot (0.5 mm in width, 0.6 m in length) was cut in a waveguide. A conductor as a simulation of one plasma (6 mm in length, conductivity: 10 S/m) was located at the center of the slot (z = 0).

3. Results and Discussions

In the experiment, pseudo-continuous line plasma was realized using argon gas at a slot gap of 0.3 mm. High-speed camera observation revealed that pseudo-continuous line plasma was realized by movement of small plasmas, like as the case of He plasma. To investigate the mechanism of the small plasma movement, simulation was carried out. Figure 2 shows intensities of microwave electric field along the slot in the cases of with and without the plasma. Without the plasma the electric field was almost constant along the slot. With the plasma, however, the microwave electric field shows spatial variation inside the plasma, i.e., higher electric field at downstream region of the plasma compared with that at upstream region. These results qualitatively suggest that the electric field intensity inside the plasma varies depending on the direction of the microwave propagation.

Reference

[1] H. Suzuki, S. Nakano et al.: The 61st JSAP Spring Meeting, Kanagawa(2014) 17p-F3-1, 17p-F3-2.

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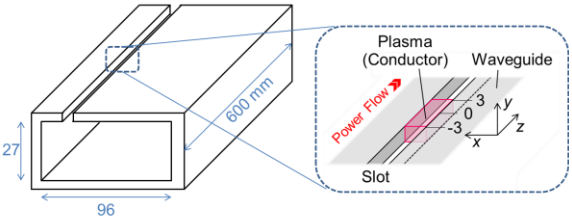

Fig.1. Schematic of model geometry for EM simulation.

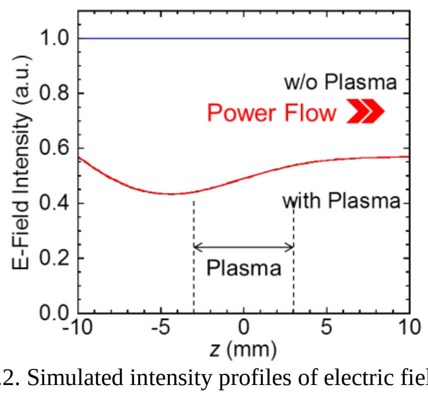

Fig.2. Simulated intensity profiles of electric field.