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大気圧マイクロ波放電による長尺ラインプラズマの生成と基礎特性
Production of long-scale line plasma excited by atmospheric-pressure microwave discharge and its characteristics

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1. Introduction

Recently, atmospheric-pressure (AP) plasmas have been given much attention because of its cost benefit and a variety of possibilities for industrial applications such as low temperature and large-area surface treatment. Among various AP plasma sources, microwave plasma produced inside slotted waveguide antennas is attractive because this plasma source can easily realize non-thermal, stable, and high-density plasma and we have proposed a newly-designed AP microwave line plasma source composed of a loop waveguide and a circulator that utilizes not standing wave but travelling wave in the waveguide. By using this plasma source, it was demonstrated that spatially uniform AP line plasma of 40 cm length was realized with helium gas and two different types of plasma mode were observed by a high-speed camera under different discharge conditions such as slot gap width and microwave power. “Pseudo” line plasma mode, i.e., plasma movement along the slot, changed into “real” line plasma mode, i.e., spatiotemporally uniform plasma along the slot, by reducing the slot gap width and increasing the peak microwave power.[1] To understand mechanism of the two modes, plasma behavior was observed using the high-speed camera in detail and simulated using electromagnetic (EM) field simulation software and one-dimensional diffusion model including spatial distribution of the ionization rate in one moving plasma.

2. Experimental

Pulsed-microwave power (pulse-frequency: 20 kHz, duty cycle: 20-100%, peak power: 1.0 kW) was supplied to the loop waveguide through an EH tuner. A section of the loop waveguide with a long slot (60 cm length, 0.1-0.7 mm width, 1.0 mm thickness) connected to a vacuum chamber was vacuum-sealed by two airtight windows and evacuated by a rotary pump. After the evacuation, helium gas was introduced into the vacuum-sealed part through small holes on the waveguide wall at total flow rates of 5.0 slm to fill the chamber and the waveguide at a pressure of 100 kPa.

3. Results and Discussions

The plasma looked spatially continuous along the slot in time average, but was discrete in wide gap width (>0.2 mm) under low duty cycle condition (“pseudo” line mode). Under 0.1 mm gap width condition, the plasma speed and size increased at a high duty cycle (>80 %) and plasma became spatially continuous inside the slot (“real” line mode). Figure 1 shows a phot of plasma emission in the “real” line plasma mode. Although there is emission intensity fluctuation near the both slot edges, high uniform and continuous line plasma is realized. To find out the cause of the fluctuation, EM simulation in the slot with plasma was performed. Figure 2 shows the simulated distribution of electric field intensity along the slot. For the most part of the slot, electric field remains stable, but a slight fluctuation in the vicinity of the slot edges is observed, suggesting that small reflection power generated at the slot edges disturbs electric field in the vicinity of the edges. I will report about the “pseudo” mode including the mechanism in my presentation.

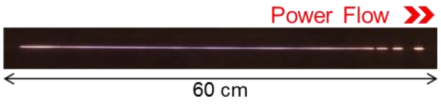

Fig. 1. Phot of plasma emission in the “real” line mode.

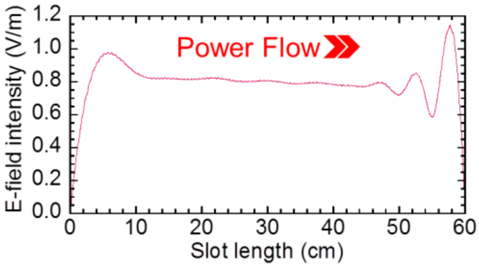

Fig. 2. Simulated distribution of electric field intensity.

Reference

[1] H Suzuki et al.: Appl. Phys. Express **8** (2015) 036001.

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