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Timing Control of Self-organized Dielectric Barrier Discharge and Influence of Discharge Driving Frequency

自己組織化誘電体バリア放電の放電タイミング制御と放電駆動周波数の影響

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A two-dimensional array of filaments generated by the self-organizing phenomenon of dielectric barrier discharge has applications in plasma photonic crystal. The net generation time for the self-organized structure in one cycle will be short, because of its self-extinguishing feature, but we attempted to improve the net generation time by the time difference to drive these parallel array discharge units. As a result, the duty cycle of the discharge current duration per cycle was 6% (single cell), 12% (two parallel cells), and 27% (three parallel cells). When the frequency changed, the generation time was 0.7 μs (100 kHz), 1.2 μs (200 kHz), and 1.5 μs (300 kHz) of the 10 μs.

1. Introduction

The microgap dielectric barrier discharge (DBD) produces a self-organization phenomenon in which the filament is structured autonomously under certain conditions. A two-dimensional array of plasma filaments has applications in plasma photonic crystals (PPCs) [1]-[3]. The control of the electromagnetic waves is difficult because the self-organized structure in the DBD is self-turned off and electron density is about 1×10^{9} cm^{-3}.

In our study, we aimed at a high densit y of plasma filaments and increased the generation time for self-organization. To improve the maintenance time, we made a difference in the generation of the self-organized structure in parallel to the discharged part. In addition, we investigated the change in plasma density when the driving frequency was changed to 100-300 kHz.

2. Experiment

Figure 1 shows the DBD driving circuit. The capacitor is charged by a DC power supply (MATSUSADA PLE-120-0.6). The time of the voltage applied to cells is controlled by the metal-oxide-semiconductor field-effect transistors (MOS-FETs) of the circuits, which signal from the turn on of a single peripheral interface controller (PIC) microcontroller. We applied the increased voltage of the pulse transformer to the microgap. Figure 2 shows the microgap discharge cells. The microgap consisted of a drive electrode, dielectric spacer, dielectric, and ground electrode. It had a 10 × 15 mm^2 discharge area and 530 μm thickness of the dielectric. Type 1 is a single discharge cell, Type 2 consists of two integrated discharge cells, and Type 3 has three integrated discharge cells. In Type 3, a copper plate (91×91 mm^2) of the grand electrode makes the electric field uniform. We generated the

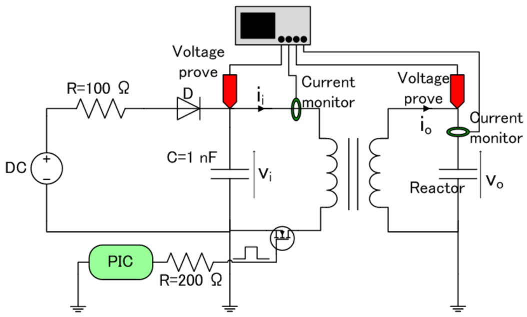

Fig. 1. Driving circuit

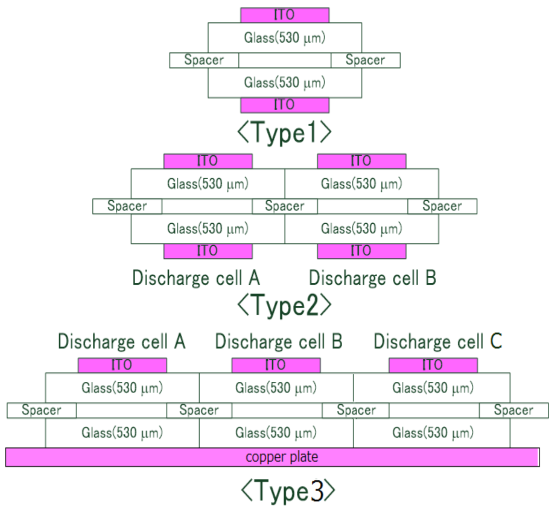

Fig. 2. Microgap discharge cells

plasma at atmospheric pressure, and we introduced helium gas.

3. Results

Figure 3 shows a waveform of the applied voltage and a discharge current when a Type 2 discharge cell was ignited. We applied a voltage of

550 V and a gas flow of 0.6 L/min, with driving frequency of 100 kHz. The time difference of the output pulse signals on the PIC microcontroller was 0.6 μs. Figure 3shows the discharge current according to the time difference. The duty cycle of the discharge current duration per cycle was approximately 13.0%.

Figure 4 shows the waveform of the applied voltage and the discharge current when a Type 3 discharge cell was ignited. We applied a voltage of 1000 V and a gas flow of 2.0 L/min, with a driving frequency of 100 kHz. The discharge current of Type 3 was the the three sum of currents measured at the ground electrode. The duty cycle of the discharge current duration per cycle was approximately 27%.

Figure 5 shows the net generation time when the driving frequency was changed to 100-300 kHz. The plasma conditions included an applied voltage of 500-600 V and a gas flow of 1.0 L/min. The generation time was not changed much in the applied voltage, but it increased with the driving frequency. The generation time was 0.61-0.72 μs (100 kHz), 0.99-1.13 μs (200 kHz), 1.43-1.89 μs (300 kHz) of the 10 μs.

Figure 6 shows the plasma density of Type 1 when the driving frequency was changed. The plasma density did not change much with the applied voltage, but it increased with the driving frequency. The plasma density was 0.85×10^{10} -1.31×10^{10} cm^{-3} (100 kHz), 1.78×10^{10} - 2.31×10^{10} cm^{-3} (200 kHz), and 3.17×10^{10} - 4.45×10^{10} cm^{-3} (300 kHz).

4. Conclusions

The duty cycle of the discharge current duration per cycle was 6% (Type 1), 12% (Type 2), and 27% (Type 3). Therefore, parallelizing the discharged part increased the duty cycle. In addition, the plasma density and generation time increased when the driving frequency of the circuit increased.

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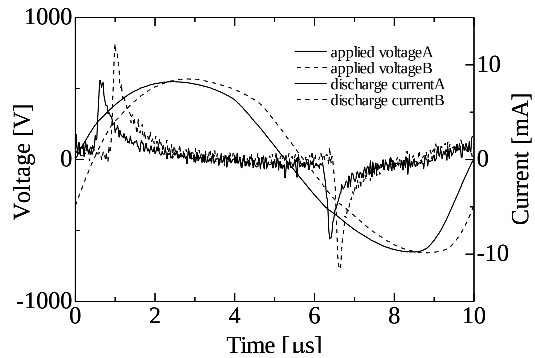

Fig. 3. Applied voltage waveform and discharge current

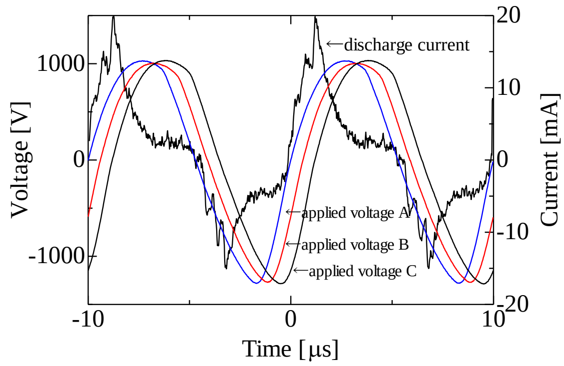

Fig. 4. Applied voltage waveform and discharge current of three parallel times

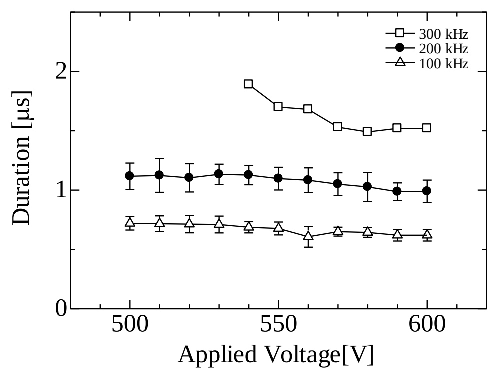

Fig. 5. Changed of the generation time with respect to driving frequency

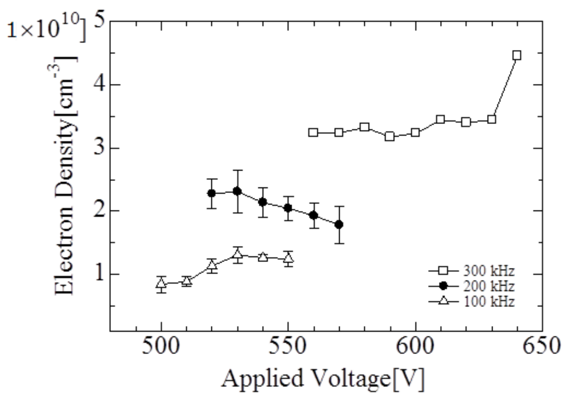

Fig.6. Change of electron density with respect to driving frequency