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Plasma Current and Temperature Measurements of Atmospheric Pressure Plasma
大気圧非平衡プラズマにおけるプラズマ電流及び温度測定

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We have studied atmospheric pressure plasma jets using a quartz tube, helium gas and electrodes by applying radio frequencies and high voltages. To study the characteristics of the jet, the plasma current was measured using by a current probe. The plasma current was estimated from the displacement current from current with plasma to current without plasma. The plasma current flowed for about 5 μs and the peak current was about 22 mA at 1 slm of helium gas flow. On the other hand, the net increase temperature with plasma heat was the water temperature difference between with and without plasmas.

1. Introduction

Recently, plasma techniques under atmospheric pressure have been adopted for industrial and biological applications. Atmospheric pressure plasmas such as plasma jets are typically produced using an arc discharge, which produces a high-temperature plasma, whereas dielectric barrier discharge (DBD) produces a low-temperature plasma, which results in less thermal damage to a material surface [1,2]. As one of the applications of DBD, atmospheric pressure plasma jet have been demonstrated using a quartz tube and copper electrodes, to which a low frequency of kilohertz band and a high voltage were applied [3,4]. A plasma plume is in fact a small bullet-like volume of plasma traveling at unusually high velocities [5-9]. The plasma density and temperature have been investigated by some measurements for the potential to be used as an effective plasma supplement for various types of discharge system. The plasma density and temperature are evaluated from the plasma current.

In this study, we present the dependences of the plasma current on the helium gas flow. Moreover, to study the plasma temperature, the plasma heat capacity is measured using by a thermometer in the irradiated water.

2. Experimental Setup

Figure 1 shows schematic diagrams of the atmospheric pressure discharge system using a tube and electrodes, and measurement system. The dielectric tube is made of quartz, and its inner and outer diameters about ϕ1.5 mm and ϕ3.0 mm, respectively. The powered and grounded electrodes are made of copper foil with 20 mm x 20 mm and a thickness of 0.1 mm. The distance between the electrodes is set at 40 mm. The helium gas flow is controlled by a gas flow meter. The power supply system (LHV-13A, Logy Electric) has a voltage of +9 kV to -6 kV and a frequency of ~13 kHz. The applied high voltage and circuit current are measured by high voltage probe (P6015A, Tektronix) and current probe (CURRENT MONITOR MODEL 4100, PEARSON). The plasma jet irradiates to pure water 50 ml. The water temperature is measured using by thermometer (1521 FLUKE).

3. Experimental Results

The time evolutions of the applied voltage and circuit currents with and without plasmas are shown in Fig. 2 at 1.0 slm of helium gas flow. The total circuit current with plasma contains the plasma current and supply current. The plasma current is estimated as the displacement current on the circuit current. The time evolutions of the displacement current are shown in Fig. 3. It is found that the plasma current flows for 5 μs and the peak current is about 22 mA. The rise time of plasma current is about 0.5 μs and the fall time is 4.0 μs. It is

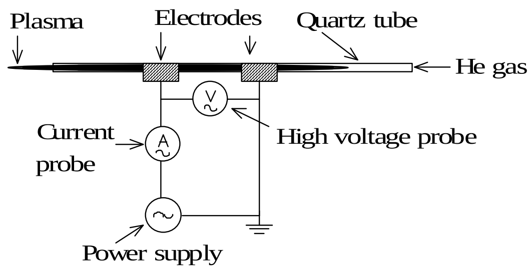

Fig. 1. Schematic drawing of atmospheric pressure discharge and measurement systems

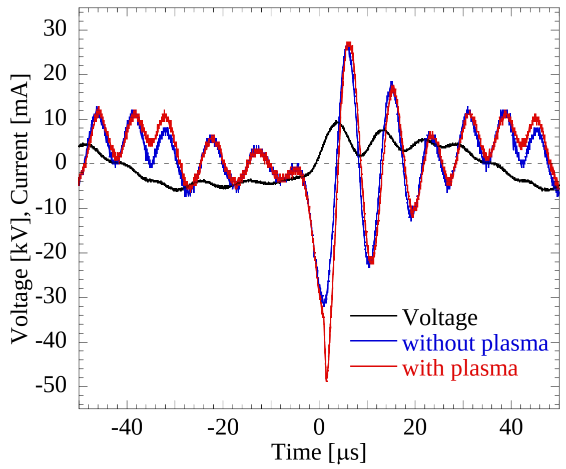

Fig. 2. Time evolutions of applied voltage and circuit currents with and without plasmas.

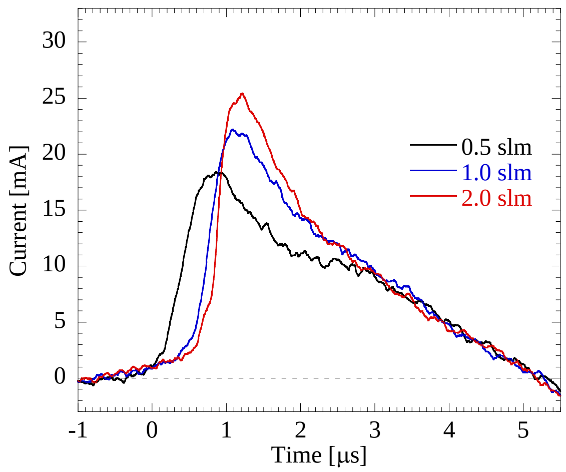

Fig. 3. Time evolutions of displacement currents at 0.5, 1.0 and 2.0 slm.

confirmed that the plasma is generated with rapid rising voltage phase. The plasma electric energy is estimated as about 0.36 mJ from the applied voltage and the plasma current. Figure 3 shows that the peak current increases in proportion to gas flow. The electric charge increases also with gas flow.

The plasma density and temperature are evaluated from the plasma current. However, the plasma temperature does not depend on the thermal velocity of electron on the atmospheric pressure. In order to investigate the plasma heat effect, the time evolutions of the water temperatures with and without irradiated are shown in Fig. 4 at 50 ml of pure water and 1.0 slm of helium gas flow. The water temperature without heating is equal to room temperature. In the case without plasma, the water temperature decreases by the influence of insulation expansion of helium gas from the gas cylinder. In the case with plasma, the water temperature increases by the plasma heat. The net increase temperature with plasma heat is the temperature difference between with and without

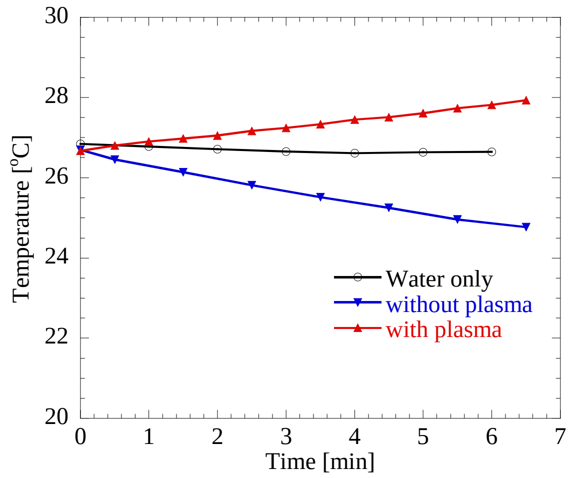

Fig. 4. Time evolutions of water temperatures with and without plasmas of pure water 50 ml.

plasmas, and the increase temperature is estimated as about 0.385 ℃/min. Here, the cycle of plasma generation is about 13 kHz, the single-plasma electric energy is estimated as about 0.1 mJ. The rate of the plasma jet which diffuses to the atmospheric is about 28 %.

4. Summary

We studied the dependence of plasma current on the helium gas flow and the plasma heating effect. The plasma current was estimated from the displacement current on the circuit current. The plasma current increased in proportion to gas flow. The water temperature increased by plasma irradiated. The plasma electric energy was estimated from the increase water temperature. Thus, the plasma temperature will be able to estimate with a drift velocity of electron current by time of flight method of the plasma bullet.

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