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Discharge characteristic of atmospheric plasma generated using water-dielectric multi-layer electrode

水 - 誘電体多層電極を用いた大気圧プラズマの放電特性

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For generation of atmospheric glow discharge plasma, deveropment of discharge method using coaxial water-dielectric multi-layer electrode were carried out. In the case of coaxial electrode, the stable Ar glow plasma was generated. The increase of temperature and decrease of dielectric constant of internal fluid affects the improvement of plasma density and stability of atmospheric discharge. And stability mechanism of internal fluid is spatially effective on surface of inner glass tube.

1. Introduction

In general, Atmospheric plasma is generated using discharge electrodes which are stuck or coated the insulator in the metal electrode in order to suppress the arc discharge and localization of electric discharge. And electric property of electrode and insulator and condition of junction seems to influence the discharge characteristic.

In this study, in order to improve the discharge property and stability of atmospheric glow discharge plasma, development of f discharge method using coaxial water-dielectric multi-layer electrode were carried out.

2. Experimental Setup

Experiments were carried out using coaxial water-dielectric multi-layer electrode shown in figure 1. The inner glass tube was inserted center of the outer glass tube which is 90mm in length, and outer glass tube was being sealed by silicon rubber cork. The inner and outer glass tube was made of borosilicate glass. The diameter of inner and outer glass tube were 6mm and 18mm respectively, and thickness of glass tube is 1mm. Between inner and outer glass tube, the internal fluid was being enclosed. The inner electrode covered with alumina tube was inserted center of glass tube. The outer cylindrical electrode (width is 10mm) was placed over the outside of outer glass tube.

Table I. Electric property of internal fluid
($D=3.36\times10^{-30}$ C·m)

	σ (S/m)	ε_r	p
tap water	$\sim10^{-2}$	80	1.85D
methanol	3.0×10^{-5}	33	1.69D
toluene	1.4×10^{-5}	2.4	0.36D

The high voltage ac power supply (10kHz, $9kV_{p-p}$) was connected with inner electrode and outer cylindrical electrode, and the potential of outer cylindrical electrode was equal to the of ground and external electrode which was placed in order to draws the plasma outside of discharge region. The discharge gas is supplied from the gas inlet connected with glass tube. Argon and oxygen gas was used, pressure of gas is 1 atm and flow rate is 3 L/min. By applying discharge voltage to inner and outer electrode, the atmospheric plasma was generated and extracted from inside of the inner glass tube.

In this investigation, water, ethanol and toluene were used as internal fluid. Ethanol and toluene is superior insulating material, and water and ethanol have high dielectric constant ε_r and high electric dipole moment p (Table I). In addition, it is noted that the dielectric constant ε_r of water and ethanol remarkably decreases with the increase in the

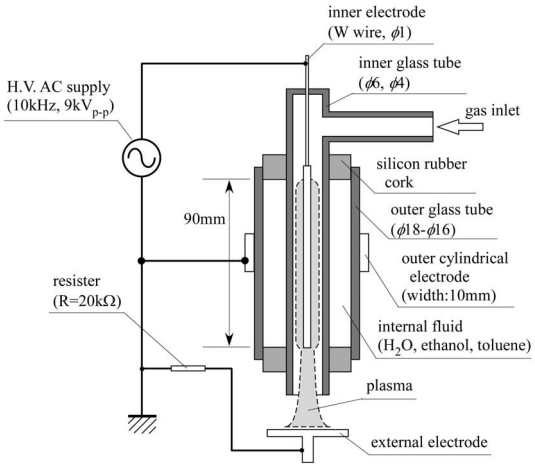

Fig.1 Experimental setup

temperature.

In addition to previous setup, glass bulb condenser (Allihn condenser) with H_2O as internal fluid, which has the length of 300 mm, was used in order to generate the large volume atmospheric plasma.

3. Experimental result

Typical image of atmospheric plasma generated by coaxial water-dielectric multi-layer electrode and glass bulb condenser were shown in Fig.2. In the case of coaxial electrode (Fig.2(a)), the stable Ar glow plasma was generated and reach external electrode, and length of glow plasma run into 30mm. The conductivity of internal fluid is not required for this discharge (Fig.3). During discharge, temperature of internal fluid and emission intensity increase with the discharge time, and H_2O and methanol are remarkable. On the other hand, in the case of toluene, temperature and emission intensity hardly change. It is considered that the fluid heating is dependent on the electric dipole moment of fluid (Table I), and dielectric constant of fluid decrease in the increase of temperature. This result indicates that the increase of temperature and decrease of dielectric constant of internal fluid affects the improvement of plasma density and stability of atmospheric discharge.

In the case of glass bulb condenser (Fig.2(b)), large volume Ar plasma stably generated in inner glass tube. Especially, in spite of the change of the diameter of the inner glass tube, the plasma was uniformly generated. This result suggests that stability mechanism of internal fluid is spatially effective on surface of inner glass tube.

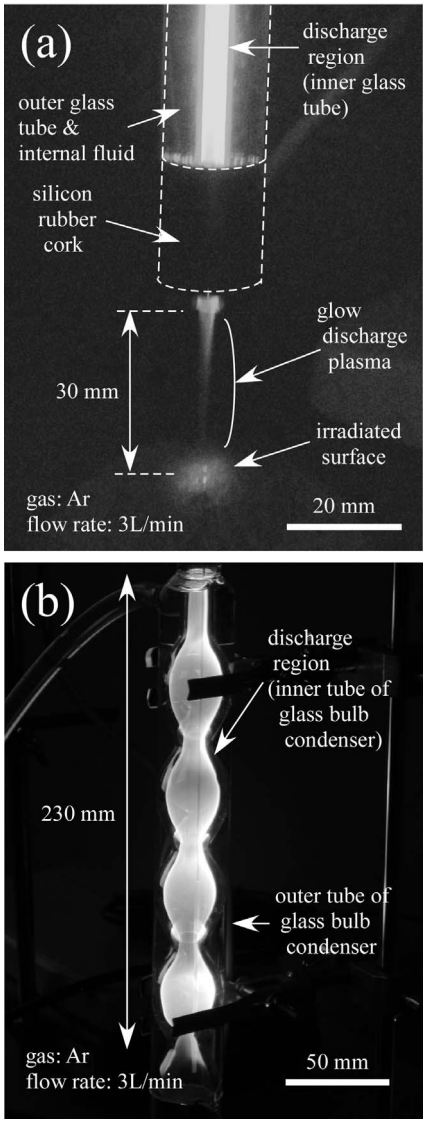

Fig.2 Typical image of atmospheric discharge using water-dielectric multi-layer electrode. (a): straight inner grass tube(Fig.1), (b): using glass bulb condenser (Allihn condenser).

Acknowledgments

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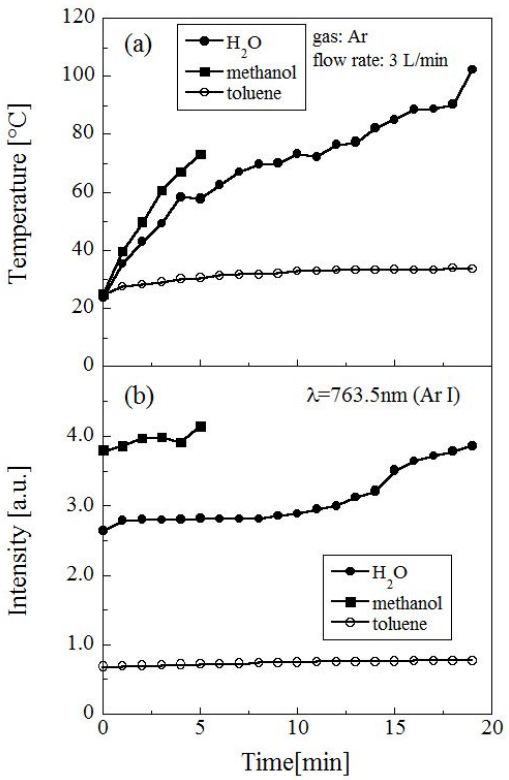

Fig.3 Time evolution of temperature of internal fluid and emitted light intensity from Ar plasma using water-dielectric multi-layer electrode. (a): Temperature of fluid, (b):light intensity measured by multi channel spectrometer. In the case of methanol, temperature of fluid exceeded the boiling point after 5 minutes from the start, and experiment was stopped.