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Measurement of OH radicals in atmospheric pressure helium plasma using laser induced fluorescence

レーザー誘起蛍光法による大気圧ヘリウムプラズマジェット中のOHラジカル計測

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Two-dimensional distribution of OH radical and air-helium mixture ratio in atmospheric pressure helium plasma jet were measured using laser induced fluorescence (LIF). The air-helium mixture ratio in the plasma jet was measured using the quenching rate of OH on excited state. The plasma jet was generated by an ac high voltage (10 kV peak-to-peaks, 7 kHz). Maximum density of OH radical was 0.1 ppm and density distribution of OH radicals in the plasma was similar to the shape of the plasma jet. The results suggest that OH radicals were generated inside of the plasma jet.

1. Introduction

Atmospheric-pressure helium plasma jet is one of the non-thermal plasma. This plasma is gathering much attention because of its high energy efficiency and extremely low heat load. These days, many biological researches were done using this plasma such as sterilization or cell activation[1.2]. In these plasma processes, active species generated by plasma such as radicals or ions play important role.

It is thought that this plasma can generate various active species in air in the reaction of plasma with ambient air[3]. However, generative mechanism of active species and their quantity have not been measured because quenching effect is complex all along with the mixed air in the plasma.

OH radical plays important role in many plasma processes because it is chemically reactive. In this study, we measured OH radical density and their two-dimensional distribution in the helium plasma jet by laser induced fluorescence (LIF).

2. Experiment

2-1. Atmospheric pressure helium plasma jet

Schematic diagram of atmospheric pressure helium plasma jet is shown in Fig. 1. This shrinking plasma jet is generated by applying high voltage from the surface of glass tube in which helium gas flows.

Microscopically, this plasma jet is made of the intermittent propagation of ionization front called plasma bullet[4]. Plasma bullet is usually ring shape or sphere and it changes its shape and speed of propagation in relation to electrical polarity and wave profile of applied voltage[5]. This unique propagation has strong relation with mixed air into

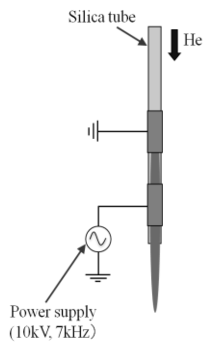

Fig. 1 Schematic diagram of atmospheric pressure helium plasma jet

the plasma and generative mechanism of active species in the air[6]. In this study, plasma was generated by ac high voltage (10 kV peak-to-peak, 7 kHz).

2-2. LIF investigation

LIF investigation has high resolution of time and space and is used widely in plasma diagnostics. Energy diagram of OH radical in LIF investigation is shown in Fig. 2. Most excited OH radicals lose their energy by the quenching effect by mixed air in the plasma and the decay time of fluorescence of OH radical strongly depends on air-helium mixture ratio in the plasma jet. The equation of relation between air-helium mixture ratio and the decay time of fluorescence of OH radical is

$$I_{LIF} \propto e^{-Qxt}(N_0A_0 + N_1A_1e^{-Q_vxt}). \qquad (1)$$

The I_{LIF} is signal intensity of fluorescence of OH, x

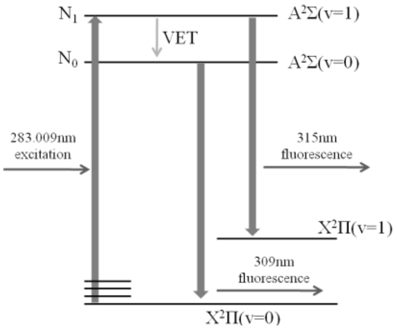

Fig. 2 Energy diagram of OH radical

is air-helium mixture ratio, Q is quenching rate coefficient and Q_v is vibration energy transfer (VET) rate coefficient. In equation(1), x is the only variable number, therefore, air-helium mixture ratio can be estimated from the decay time of I_{LIF}. In this study, air-helium mixture ratio can be simultaneously measured with the density of OH radicals in each position.

3. Experimental conclusion

Two-dimensional distribution of OH radical is shown in Fig. 3. It shows that OH density decreases with increasing the distance from center of the plasma jet. Shrinking distribution area of OH radical matches shape of the plasma jet, therefore, it also shows most of OH radicals exist inside of plasma jet. Maximum OH density in the plasma jet was approximately 0.1 ppm.

Fig.4 shows two-dimensional distribution of air-helium mixture ratio. The mixture ratio increases with increasing the distance from center of the plasma jet as well as OH density distribution. On the inside surface of the plasma jet, it revealed that approximately 80 percent of composing gas of plasma is the mixed air. This result qualitatively matches the result of fluid calculation in previous research[7].

4. Conclusion

Two-dimensional distribution of OH radical and air-helium mixture ratio were successfully measured by LIF investigation. The air-helium mixture ratio is one of the most important factors for this plasma jet because it has strong relationship with generation of various active species and propagation of plasma bullet in the air.

The method used in this study revealed useful because two important parameters, the air-helium mixture ratio and absolute density of active species, can be measured at once.

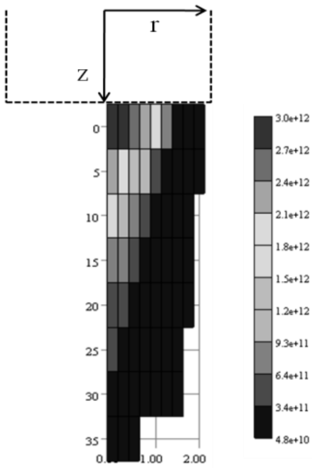

Fig. 3 Two-dimensional distribution of OH radical
(The unit in a right chart is the number of OH radicals per cubic centimeter)

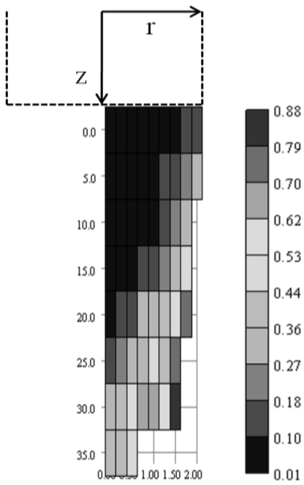

Fig. 4 Two-dimensional distribution of air-helium mixture ratio
(The number in right chart is the air ratio versus helium in plasma)

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