18PB-072

Investigation of Correlation between OH Radical Production Rate Induced in Liquid and Radical in Gas Phase in Low Frequency Atmospheric Pressure He/O_2 Plasma Jet

O_2添加He低周波プラズマジェット照射により誘起されるOHラジカル生成速度と気相中ラジカルとの相関性調査

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Many kinds of chemical species are induced in liquid during atmospheric pressure plasma jet (APPJ) irradiation. Production rates of these chemical species are much related to chemical reaction in liquid. So that it is important to know how to control these production rates. Additional gas is one of the factors to control chemical species production rate by irradiating APPJ in liquid. We used the working gas as pure He or adding the small amount of O_2 gas to He. We observed the optical emission spectra by multichannel spectroscope as a gas phase investigation. And then we measured OH radical production rate in liquid.

1. Introduction

Non-thermal atmospheric pressure discharges (NAPDs) have been widely used since it has low temperature. NAPDs can treat without thermal damage. For example, NAPDs are used in the surface modification, making new material, the medical treatment [1,2], the agriculture and so on.

Low frequency atmosphere pressure plasma jet (LFAPPJ) is one of the NAPDs. LFAPPJ is convenient plasma source because it does not need the expensive equipment like a vacuum apparatus. We are trying to adopt LFAPPJ for new fabrication process using water. [3]. To improve LFAPPJ for applying fabrication, it is important to understand the plasma-liquid interactions. The irradiation of LFAPPJ induces many kinds of radicals and chemical species in liquid. These species are the key of chemical reaction in liquid. In this paper, we present the effect of using admixture gas for LFAPPJ working gas. In general, LFAPPJ is used in atmosphere of the air, therefore, it is important to know the effect of the air to plasma-liquid interactions. We used He gas for the main working gas and O_2 gas for adding gas. We investigated OH radicals production rate in liquid to understand the effect of O_2 adding for liquid phase. In addition, we investigated optical emission spectra to understand the effect of O_2 adding for gas phase.

2. Experimental Apparatus

Figure 1 shows the schematic view of the experimental setup. Plasma was produced in a capillary made of quartz and surrounded by aluminum tape. The quartz has 1.9 mm inner diameter and 4.0 mm outer diameter. A power source which can apply low frequency (~20 kHz) and high voltage (~17 kV) was connected to the aluminum tape. He and He/O_2 gas were used as a working gas. O_2 is including in air and molecular gas. He flow rate was fixed at 3 slm and O_2 flow rate was varying from 0 sccm to 200 sccm. A cylindrical vessel which made by polytetrafluoroethylene was set up under the quartz capillary. Ultrapure water was poured in the vessel. A volume of ultrapure water was 800 µL.

Optical emission spectra were measured by multichannel spectroscope. The observation point was 3 mm upper from ultrapure water surface.

When we investigated OH radicals in liquid, terephthalic acid (TA) solution was poured in the vessel instead of ultrapure water. TA volume was also 800 µL. The vessel was made by polytetrafluoroethylene and put on a metal plate which connected to the ground. The distance between the tip of quartz capillary and the surface of TA solution (d_{NOZ}) was fixed at 8 mm.

3. Results and Discussions

3.1 *OH radicals in liquid*

OH radicals induced in liquid were measured by chemical probe. TA was used as a scavenger of OH radicals. TA highly reacts on OH radical and forms 2-hydroxyterephthalic acid (HTA). The HTA is excited by 315 nm UV and fluorescent at 425 nm. Therefore, HTA concentration can be measured by measuring 425 nm fluorescent intensity [4-6].

The HTA concentration was measured with varying O_2 flow rate less than 200 sccm. We calculated the amount of HTA by the HTA concentration and the liquid volume. The amount of HTA increased while O_2 flow rate was less than 20 sccm and decreased when O_2 flow rate was more than 20 sccm.

3.2 *Optical emission spectroscopic diagnostics*

The optical emission spectra of LFAPPJ were measured with varying O_2 flow; 0 sccm to 200 sccm. Figure 2 shows the typical radiation intensity of LFAPPJ. O_2 gas added 0, 6, 15 sccm, respectively. Optical emission spectra were measured through a lens and optical fiber. It was found that OH (307.8 nm), N_2 1st-negative (337.1 nm), N_2 2nd-positive (391.4 nm), He (706.5 nm), O (777.1 nm) and O (844.6 nm) emission. OH, He and N_2 2nd-positive emission spectra decreased with increased O_2 gas flow rate. On the other hand, N_2 1st-negative and both of O emission spectra were stronger than O_2 gas flow rate was 0 sccm when O_2 gas injected 6 sccm.

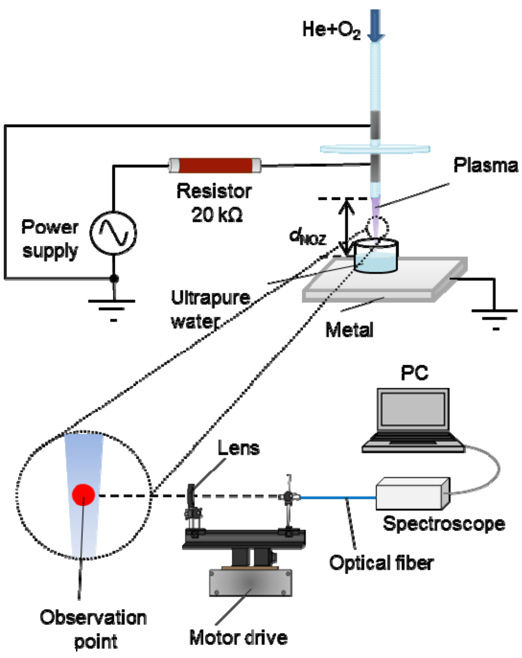

Fig. 1 Experimental setup for measuring optical emission spectra.

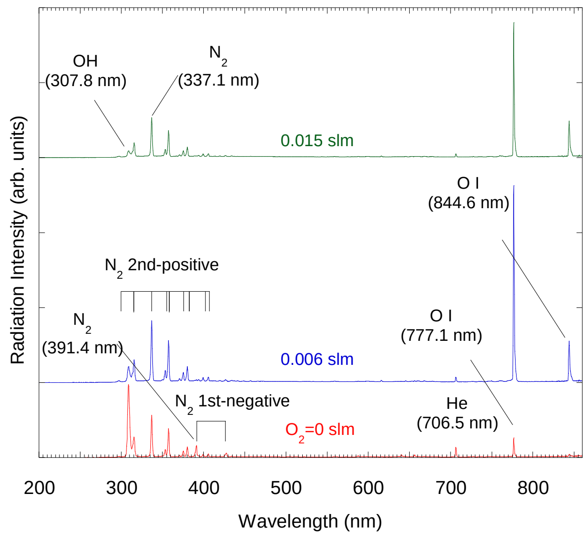

Fig. 2 Optical emission spectra of LFAPPJ.
The working gas of LFAPPJ is He 3 slm (red), He 3 slm+O_2 6 sccm (blue), He 3 slm+O_2 15 sccm (green), respectively.

4. Summary

In this paper, we have studied about He/O_2 LFAPPJ by two methods. We measured OH radical by chemical probe using the TA solution and the optical emission spectra using multichannel spectroscope. The amount of HTA increased while O_2 gas flow rate is less than 20 sccm. N_2 1st-negative (337.1 nm) and O (777.1, 844.6 nm) emission spectra increased in O_2 gas flow rate is about 6 sccm. These results suggested that OH radical induced in liquid in rerated with N_2 or O radicals in the gas phase.

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