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Decomposition of methylene blue by laminar gas-fed atmospheric pressure plasma jet using double coaxial glass tube

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1. Introduction

In recent years, research on an atmospheric pressure plasma jet (APPJ) has been actively conducted The low-temperature plasma like atmospheric pressure plasma is characterized by its ion and neutral species being close to room temperature, whereas it generates a variety of active components such as hydroxyl radicals and ozone. These active species have the ability to decompose and remove organic compounds. Therefore, it is possible to realize valuable tools for surface treatment such as improvement of hydrophilicity on a solid substrate without any heat damage. In addition, APPJ can also be used for application in biomedical field. These applications depend on plasma-generated reactive oxygen species and reactive nitrogen species. The production of reactive species can be enhanced in many ways such as addition of other gas, however the mixing ratio was below only a few percent due to the negative reactions for stable plasma discharge.

We have developed a surrounding gas-fed plasma jet with a double coaxial glass tube for the increase of radical productions [1]. In this study, we investigated the decomposition of a methylene blue solution by the APPJ irradiation in order to evaluate the fundamental characteristics of the laminar flow APPJ.

2. Experimental setup

Figure 1 shows a schematic diagram of the experimental setup. The glass tube consists of inner and outer glass tubes. With this double coaxial structure, two different gases can introduce into the glass tube and can control each flow rate independently. Helium gas was passed through the inner path with a flow rate of 7 L/min and the core plasma was produced by the dielectric-barrier discharge. On the other hand, N_2, O_2, or air gas was passed through the outer path with 0−10 L/min. The copper films are wrapped to both sides of the flange of the inner tube as an electrode. The sinusoidal voltage of 8 kV with a frequency of 20 kHz was applied to the electrodes to generate the plasma jet. The decomposition of methylene blue was observed by optical absorption spectroscopy every 5 minutes. An initial concentration of methylene blue was set to 2.6 mol/L.

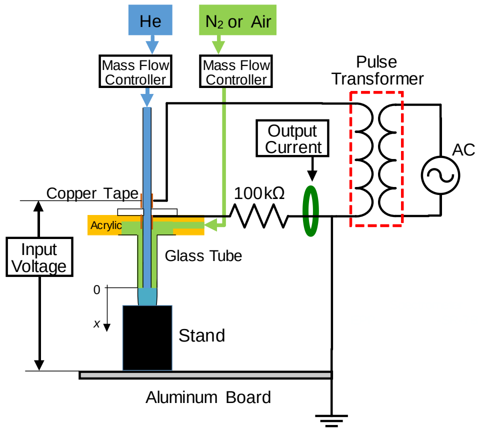

Figure 1 Schematic diagram of the experimental setup

3. Experimental results

Figure 2 shows the concentration of methylene blue solution as a function of the treatment time where the treatment distance was fixed at 15 mm. The solid circles and solid triangles are obtained for the case of the laminar plasma jet with the surrounding N_2 gas with 5 L/min and the conventional plasma jet without N_2 gas, respectively. When the methylene blue solution was irradiated with the plasma jet, the color of the methylene blue gradually became lighter with the increase the treatment time. It was found that the concentration of methylene blue decreases rapidly and tends to saturate after the treatment time of 20 min. As seen in Fig. 2, the concentration of the laminar APPJ-treated sample is smaller than the APPJ-treated one over the measured treatment time.

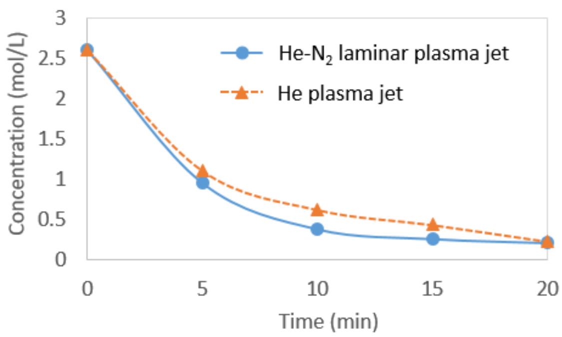

Figure 2 Concentration of methylene blue solution as a function of treatment time

4. Conclusion

In order to evaluate the characteristics of the developed laminar flow APPJ, we have evaluated the decomposition of methylene blue by exposure to an atmospheric pressure plasma jet. The decomposition of methylene blue sample treated with the laminar APPJ is faster than that with the conventional He APPJ. Thus, the laminar flow APPJ has a higher decomposition rate than the single tube structure.

References

[1] H.Ohashi, *et.al.*, "A Versatile Laminar Flow Atmospheric Pressure Plasma Jet Using a Double Coaxial Glass Tube", IEEE Trans. Plasma Sci., vol.45, pp.2481-2485, (2017).