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Fabrication of Line Type Atmospheric Pressure Plasma Jet by Dielectric Barrier Discharge

誘電体バリア放電ライン型大気圧プラズマジェットの作製

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We have been developing a line shaped atmospheric pressure plasma jet device which can eject line shaed plasma plume excited by dielectric barrier discharge. The device consists of a pair of glass plates with a small discharge gap and electrodes adhered to the outside of the glass plates. It has been succeeded to excite uniform line shaped N_2, Ar and He plasma ejected into the ambient air by optimizing the configuration of electrodes for each gas. To confirm the effective irradiation profiles, the line plasmas were irraditaed to KI-starch gel. It was found that the N_2 plasma made a uniformly irradiation image while Ar and He plasmas made nonuniform profiles. A possible reason for the nonuniform profile by Ar and He plasmas is direct discharges passing throuth the target to the electrical ground other than the electrodes.

1. Introduction

When the electrode of the atmospheric pressure plasma jet is exposed to electric discharge, it is sputtered and the irradiation object is contaminated with the electrode material. Therefore, in applications that may be affected by contamination, such as surface modification of cell culture dish, it is desirable to avoid contamination by the electrode material.

The purpose of this study is to fabricate the atmospheric pressure plasma jet device which can eject line shaped plasma (line type atmospheric pressure plasma jet) for processing of a wide area such as surface modification of a petri dish without electrode material contamination.

2. Experimental

A rectangular discharge cell, as shown in Fig.1, was prepared using two non-alkaline glass plates (Eagle XG, Corning Inc.) having a thickness of 0.3 mm and glass frit (LS-3075, Nippon Electric Glass Co., Ltd.). The inside dimension of the cell was around 32 mm in width and around 1.1 mm in height. A line type atmospheric pressure plasma jet was excited by copper tape electrodes placed on the outside of the glass plates.

N_2, Ar or He gas was supplied at a flow rate of 20 L/min, and a 25 kHz sinusoidal wave voltage at $10kV_{p\text{-}p}$ was applied to the electrode for generation of plasma.

In order to evaluate the irradiation shape and irradiation area of the plasma, we used KI-starch gel[1]. The experiments were conducted by changing the distance from the plasma outlet to the KI-starch gel (irradiation distance) to 5 mm, 10 mm and 15 mm. The irradiation time was varied depending on the type of gas and irradiation distance. The KI-starch gel was prepared by adding 0.5 wt% agarose to an aqueous solution containing 0.3 wt% potassium iodide and 0.5 wt% starch.

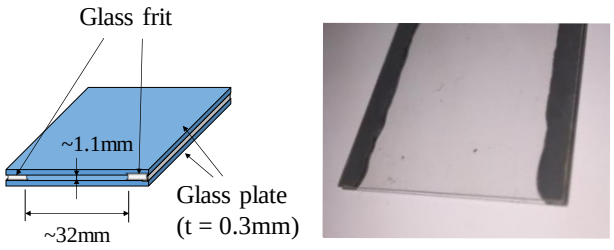

Fig.1. Structure and photograph of rectangular tube

3. Results and Discussions

By optimizing the configuration of the electrodes for each discharge gas, line shaped N_2, Ar and He plasma was successfully appeared (Fig. 2). The length of the N_2, Ar plasma was around 10 mm and He plasma was around 5 mm.

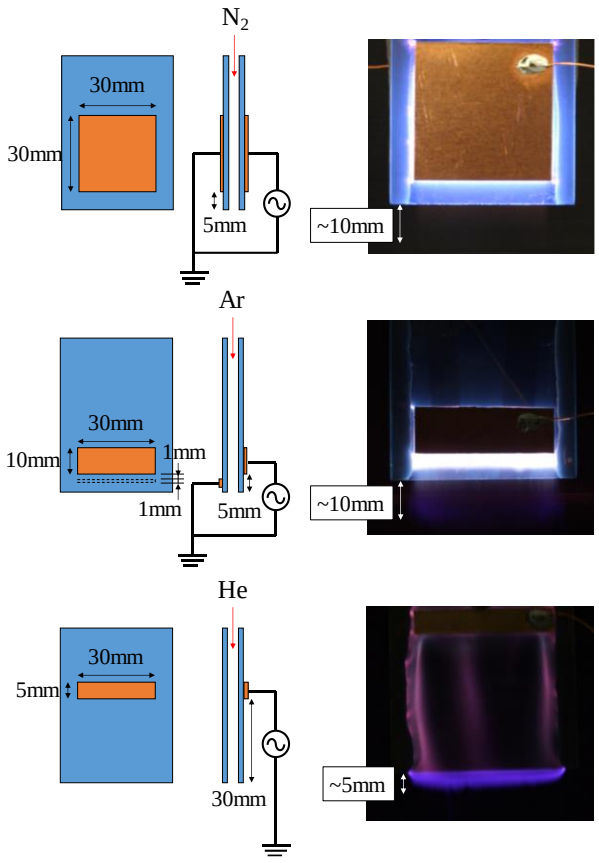

Fig.2. Structure and photographs of
line type atmospheric pressure plasma jets

The plasma jets were irradiated on the KI-starch gel and the results are shown in Fig.3. It was confirmed that the N_2 plasma was uniformly irradiated even if the irradiation distance was changed. However, Ar and He plasma became nonuniform. It is assumed to be due to partial discharge occurring between the irradiation object and plasma density distribution near the partial discharge being nonuniform. In the case of N_2 plasma, it is believed that a homogeneous plasma has been ejected since it is discharged inside the rectangular tube and the generated plasma is extruded by the gas flow.

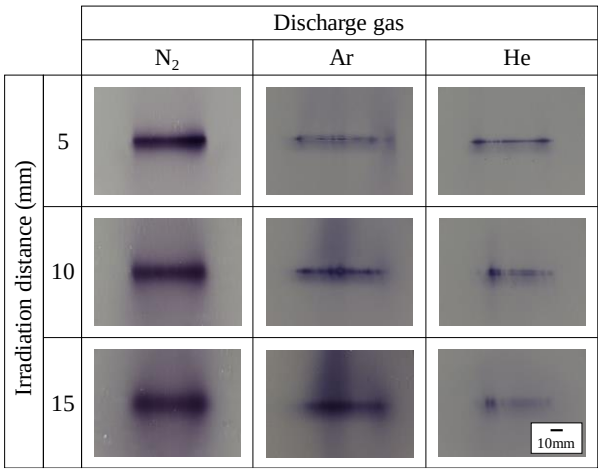

Fig.3. Irradiation shapes of
line type atmospheric pressure plasma jets

4. Summary

A line type atmospheric pressure plasma jet having an inner dimension of a discharge cell around 32 mm in width and around 1.1 mm in height was using non-alkali glass plate and glass frit and placing an electrode on the outside of the rectangular discharge cell. By flowing N_2, Ar or He gas at a flow rate of 20 L/min and applying a 25 kHz sinusoidal wave voltage at $10kV_{p\text{-}p}$ to the optimized electrode for placement, line shaped plasma was successfully ejected. The irradiation shape of the plasma jets was visualized using KI-starch gel, and it was confirmed that N_2 plasma can be uniformly irradiated. On the other hand, Ar and He plasma became nonuniform. It is assumed to be due to partial discharge occurring between the irradiation object.

In the case of N_2 plasma, the line type atmospheric pressure plasma jet capable of treating a width of around 30 mm could be realized without contamination. Therefore, for example, the surface modification of a ϕ30 mm cell culture dish can be expected.

References

[1] T. Kawasaki, K. Kawano, H. Mizoguchi, Y. Yano, K. Yamashita, M. Sakai, T. Shimizu, G. Uchida, K. Koga, and M. Shiratani: IEEE Trans. Plasma Sci. **42** (2014) 2482.