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シースフローによる液体電極を用いた大気圧グロー放電の制御

Control of atmospheric DC glow discharge with liquid electrode by sheath flow system

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Atmospheric non-thermal plasma in and in contact with liquids has attracted considerable interest in view of its potential use in a wide range of applications. Previously we investigated the fundamental characteristics of atmospheric DC glow discharge using liquid electrode. The discharge characteristics and plasma-liquid interaction depend on the gas species of the discharge. It may depend on the room condition such as humidity and temperature. To control the discharge gas in open air, we propose the method using sheath flow system. Using this system, the gas species in the electrode gap can be controlled.

Fig. 1 shows the experimental setup employed to produce an atmospheric dc glow discharge using a liquid electrode with a miniature helium flow and sheath flow system. The discharge is generated between the metal nozzle electrode and liquid electrode. Helium is fed through the nozzle electrode to the outside, and discharge is generated in ambient air. Helium flow rate is 200 sccm. Gap length is 1-10 mm. Sheath flow system enable another gas (N_2, O_2, Ar) flow to around the helium flow. It can control the gas species around the discharge. Liquid electrode is NaCl solution. Power source is DC or DC pulse.

When liquid (NaCl aq.) cathode DC discharge is generated, Na emission (588 nm) can be observed from liquid surface with increasing discharge current. Previously we confirmed the fact. Na emission strongly depends on the discharge current and liquid temperature[1]. When N_2 or O_2 sheath flow is used to the liquid cathode discharge, the intensity of Na emission is not changed. On the other hands, when Ar sheath flow is used, the intensity of Na becomes weak. Figure 2 shows typical time histories of the Na atomic line at 588 nm and the nitrogen second positive system at 337 nm when the DC pulsed discharge is generated. In the case of N_2 sheath flow discharge, Na has a delay time of about 100 μs relative to the inception of voltage while the nitrogen second positive band does not have the delay. The delay time depend on the local heating of the liquid surface. In the case of Ar sheath flow discharge, delay time of Na becomes 800 μs. It hypothesized that plasma-liquid interaction can be controlled by changing discharge gas using sheath flow system.

Using sheath flow system, other reaction of the discharge using liquid electrode can be controlled. When liquid anode discharge is generated self-organized luminous patterns are observed on the liquid surface. We can control the pattern formation by changing the oxygen ratio in the gap[3].

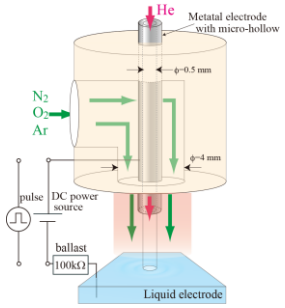

Fig. 1 Experimental setup for generating atmospheric dc glow discharge using liquid electrode with a miniature helium flow and sheath flow system.

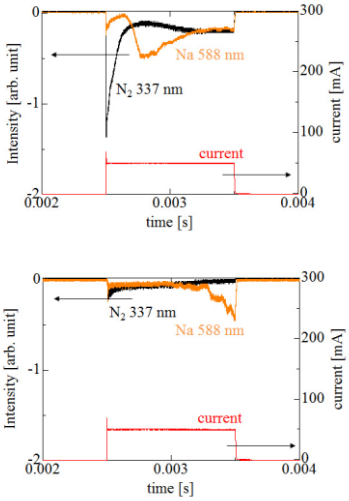

Fig. 2 Temporal change in optical emissions from the discharges powered by pulse-modulated dc voltage. (a) N_2 sheath flow (b) Ar sheath flow

When the liquid electrode discharge is generated with solution including metal cation such as $AgNO_3$ or $HAuCl_4$, metal nanoparticles (Ag or Au) can be synthesized at the liquid surface[3]. The size and shape of nanoparticles depend on the gas species. When nitrogen sheath flow plasma is used, many nanoparticles with triangle structure are generated in plasma anode side. When oxygen sheath flow plasma is used, nanoparticles become smaller in plasma cathode side.

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Reference

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[2] N. Shirai et al., Plasma Source Sci. Technol. **23** (2014) to be published.

[3] N. Shirai et al. Jpn J. Appl. Phys. **53** (2014) 046202