Influence of gas temperature and neutral particle density on self-organized luminous patterns in atmospheric-pressure DC glow discharge

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【Introduction】

When an atmospheric-pressure DC glow discharge is generated, self-organized luminous pattern formation is observed above anodes under some conditions [1]. In general, every self-organized pattern can be mathematically described by simultaneous partial differential equations with two variables, which is called “the reaction-diffusion system”. It requires two formation factors whose densities increase or decrease as a result of the reaction and the diffusion [2]. The luminous patterns are observed both in the cases that metals and liquids work as the anode of the discharge. However, the pattern formation mechanism has not been understood yet in detail. To understand the mechanism, it is important to understand the plasma characteristics when the pattern is observed. We have considered that the presence of negative ions is a key in the pattern formation because the presence of oxygen gas is important for the pattern formation [1]. On the other hand, some papers, in which the authors carried out experiments and simulations of low-pressure discharges with lower densities of neutral species than those in atmospheric-pressure discharges, reported that self-organized luminous patterns were able to be observed even in noble gas discharges [3-6]. It is suggested by these papers that, when the patterns are formed in atmospheric-pressure plasmas, a decrease in the gas density may be caused by the temperature increase. In this study, the gas temperature in atmospheric-pressure DC glow discharge is estimated based on the rotational temperature of OH radicals, and influence of the gas density on the luminous pattern formation is discussed.

【Experimental method】

Figure 1 shows the experimental setup for generating the atmospheric-pressure DC glow discharge with a miniature helium flow. 1% NaCl aqueous solution was used for the liquid anode. The cathode was made of brass with a narrow hole of 500 μm diameter which was used for flowing helium toward the anode. A DC high voltage was applied between the liquid anode and the metal cathode to generate discharge plasma. The spatial distribution of the rotational temperature of OH radicals in the gas phase was measured by laser-induced fluorescence spectroscopy at various helium flow rates (200-300 sccm), the distances between the anode and the cathode (2-10 mm), and the discharge currents (20-80 mA). The laser beam was injected from the radial direction into the plasma, and the laser-induced fluorescence was detected using an ICCD camera from right angle to the incident laser beam. The rotational temperature of OH was deduced from the relative populations of three rotational states of OH at electronic and vibrational ground state. The luminous patterns above the liquid anode were observed at the same time.

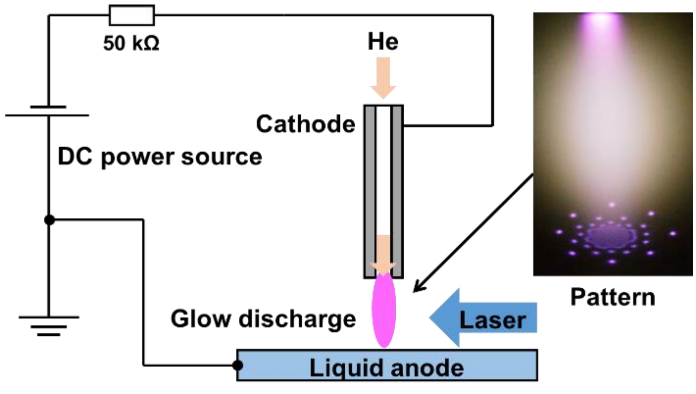

Fig.1 Experimental setup.

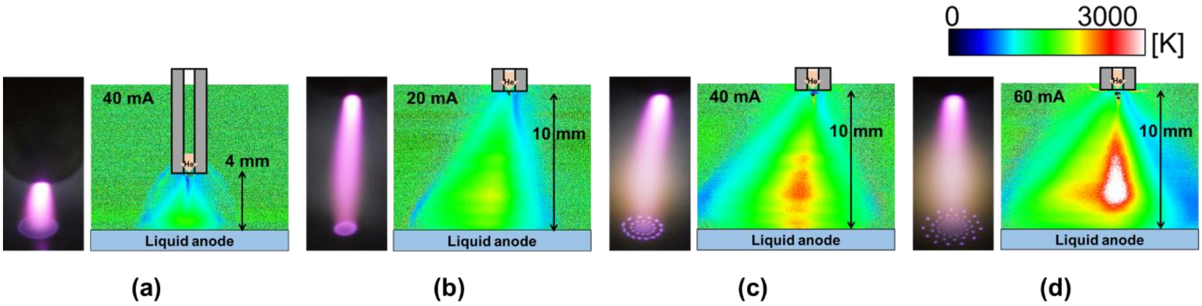

Fig.2 The rotational temperature distribution of OH radicals and the optical emission images of the discharge.

【Results and discussion】

Figure 2 shows the rotational temperature distribution of OH radicals and the optical emission image of the discharge. The helium flow rate was fixed at 300 sccm, and the discharge current and the electrode distance were varied. The luminous pattern on the anode did not form under the conditions of (a) 20 mA and 4 mm and (b) 40 mA and 10 mm, while the pattern formed under the conditions of (c) 40 mA and 10 mm and (d) 60 mA and 10 mm. Assuming that the rotational and translational temperatures are approximately equal under the atmospheric pressure, we may say that the luminous pattern is observed when the gas temperature is as high as 3000 K. In other words, the luminous pattern is formed when the gas density is as low as 10^4 Pa. References [3-6] report that the luminous patterns are observed at a certain range of the pressure. The experimental result shown in Fig. 2 also suggests that the gas density is an important parameter in the luminous pattern formation in the atmospheric-pressure DC glow discharge. As the gas density decreases, a reduced electric field (E/n) increases, which can change the mobility and diffusion coefficient of ions and electrons in the plasma. The changes in the mobilities and diffusion coefficients may alter the reaction and diffusion in the reaction-diffusion system, resulting in the pattern formation.

References

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