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Atmospheric Pressure Argon Plasma Jet Generated with Penning Discharge

ペニング放電を利用した
小型大気圧アルゴンプラズマジェットの生成

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An atmospheric pressure plasma jet generated with argon gas has been compared with the one with helium gas. The length of argon plasma jet was shorter than the helium plasma jet because the argon is difficult to maintain glow discharge. On the other hand, the argon plasma jet had much more hydroxyl radicals than the helium. In the argon plasma, metastable argon atoms with energy of 11.5 eV can be formed by bombardment of argon atoms and electrons. The metastable species dissociated H_2O molecules to OH radicals in the argon plasma.

1. Introduction

Atmospheric pressure plasmas are non-thermal and glow discharge plasma operating at an atmospheric pressure. In the plasmas, there are chemically active species such as hydroxyl radical and ozone. Therefore the plasmas can be applied on surface modification of materials and bio application [1-3].

In our early work, an atmospheric pressure plasma jet device with a high voltage modulator driven by dry cells of 12 V has been developed [4]. The plasma generated by the device has carried out decomposition of water-soluble organic dye and surface treatment of highly crystalline graphite [5]. The running cost, however, isn't economical because the plasma was generated with helium gas of 1-5 ℓ/min.

In the present work, we have generated an atmospheric pressure plasma jet with argon instead of helium in order to cut the running cost. This paper reports on a comparison of plasmas generated by helium and argon.

2. Experimental

Plasma jet nozzle has a dielectric tube and two cylindrical electrodes geometry. The quartz tube with the diameter of 1.5 mm and thickness of 0.6 mm is used as a dielectric barrier. A powered electrode is in the tube and a grounded electrode is rolled on the tube. Helium or argon gas is controlled by 1-5 ℓ/min by a flow meter and introduced to the tube.

The plasma jet is generated by an AC power supply with 6 kV and 16 kHz. Chemically active species in the plasmas were evaluated by fiber optic spectrometer (SEC2000, BAS).

3. Results

Figure 1 shows photographs of the plasmas generated with (a) helium and (b) argon gas. The flow rate was adjusted at 2 ℓ/min. It is clear from

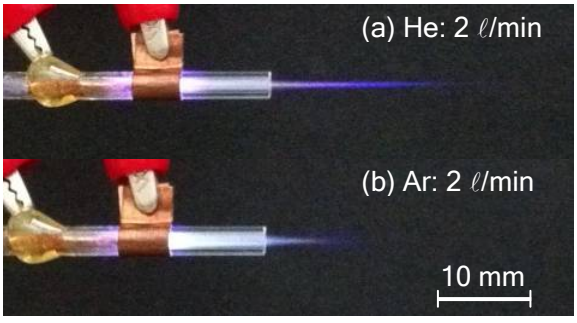

Fig. 1 Observation of plasmas generated with (a) helium and (b) argon.

Fig. 1 that the length of plasma plume with helium is longer than that with argon. The difference in the plasma length results from easiness of maintaining glow discharge.

The helium has metastable level E_m=20.6 eV under the ionization one E_i = 24.5 eV. On the other hand, the argon has also metastable and ionization level of E_m=11.5 eV and E_i = 15.8 eV, respectively. The difference between E_i and E_m levels for argon is more than that of helium. It is difficult for argon to maintain the glow discharge.

Figure 2 shows spectra of the plasmas with (a) helium and (b) argon. The helium plasma jet has hydroxyl radical OH, nitrogen molecule N_2, and metastable helium He*. The argon plasma jet has OH and metastable argon Ar*. The OH peak in the argon plasma is 7 times higher than that in the helium plasma.

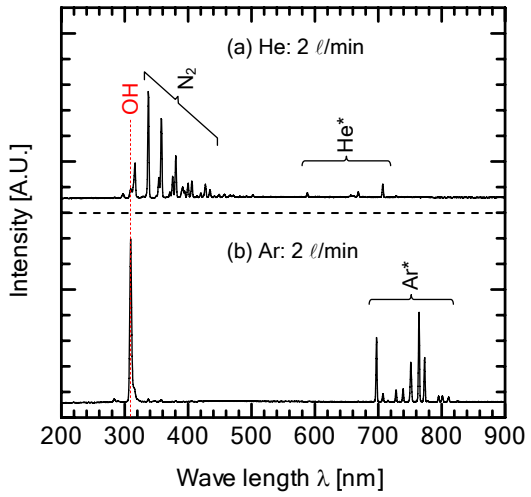

Fig. 2 Optical emission spectra of plasmas generated with (a) helium and (b) argon.

In generally, electron energy in the plasma jet is ~10 eV, which is comparable with the one of metastable argon. Therefore metastable argon species can be generated by bombardment of electron and argon atom. Dissociation energy from H_2O to OH is 5.1 eV. In the argon plasma jet, H_2O molecules can be dissociated to OH by bombardment of H_2O and metastable argon.

4. Discussion

A breakdown voltage of argon is much higher than that of helium although the argon plasma has more OH radicals than the helium. The breakdown voltage must be reduced in order to generate argon plasma jet by dry cells. Wen-Ting Sum et.al. has reported on generation of atmospheric pressure glow plasma with argon added ethanol (CH_3CH_2OH) [6]. The breakdown voltage for argon was reduced by adding ethanol due to Penning effect:

$$Ar^* + CH_3CH_2OH \rightarrow B_1^+ + D_1 + e, \qquad (1)$$

where B_1^+ and D_1 stand for the products of ions and neutrals, respectively, while e represents the electrons.

We propose an experimental setup for generation of argon plasma jet with dry cells as shown in Fig. 3. A small amount of the argon was mixed by ethanol in a flask. In this system, we experimentally generate argon plasma jet.

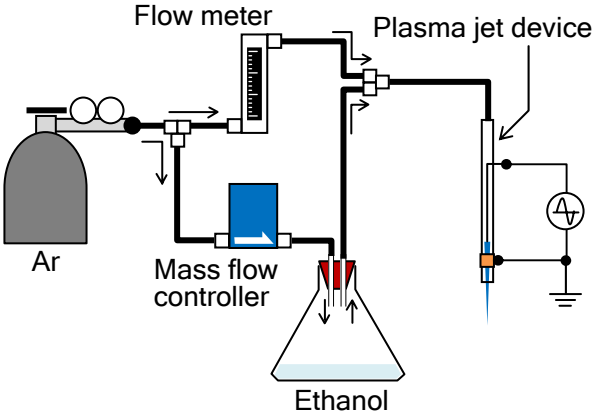

Fig. 3 Scheme of experimental setup for generation of argon plasma jet with Penning ionization.

5. Conclusion

In this paper, comparison of plasma jet generated with helium and argon. The argon plasma jet has much more OH radicals than the helium plasma jet. The breakdown voltage for argon is higher than that of helium. The voltage can be reduced by mixing of ethanol and argon due to Penning ionization.

Acknowledgement

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