17p-S10-6

Effective Production of OH Radicals in Ar Plasma Jet

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1. Introduction

An atmospheric-pressure plasma jet has recently attracted attention, because plasma generated between electrodes is pushed out to an atmosphere, allowing the plasma to reach a solid and liquid surface easily; therefore, the plasma jet can be used in the fields of plasma medicine[(1)] and disinfection[(2)]. In those fields, reactive species such as O and OH radicals and O_2^- are regarded as important species, and OH radical has the highest reactivity in the species. For the effective use of the plasma jet, it is important to increase the concentration of OH radicals produced by the plasma jet.

Takeuchi *et al.*[(3)] calculated the density of OH radical in plasma on gas-liquid interface, and reported that OH radicals produced in the plasma react with themselves to form H_2O_2. This suggests that the concentration of OH radicals may be deduced from that of H_2O_2.

In this work, we generated an Ar plasma jet with and without H_2O, exposed deionised water to the plasma jet, and then investigated H_2O_2 concentration in the deionised water after the exposure of the plasma jet.

2. Experimental apparatus and conditions

To produce the plasma jet, dielectric barrier discharge plasma is generated in a glass tube of 3 mm in inner diameter and 90 mm in length, and the plasma is pushed out of the tube by feed gas. A copper tube of 3 mm in outer diameter, used as a high-voltage electrode, is inserted in an end of the glass tube at a depth of about 10 mm, and an aluminium sheet of 15 mm in width, used as an earth electrode, is bound around the glass tube. The distance between the electrodes is fixed at 10 mm. Deionised water of 200 mL is poured into a 500 mL beaker placed directly below the glass tube, and the tip of the glass tube is 65 mm away from the water surface.

Ar gas and Ar/H_2O mixture gas are fed into the glass tube through the copper tube at a constant flow rate of 10 L/min. A sinusoidal high-voltage of 13 kV_{p-p} with a frequency of 17 kHz generated by a neon-sign-transformer (Kodera, CR-N16) is applied to the copper tube, generating the plasma jet. The deionised water is exposed to the plasma jet for 15 min, and a sample of 1.2 mL is taken every 3 min. H_2O_2 concentration is measured using High Performance Liquid Chromatograph (Shimadzu, Prominence, column: IC NI-424). The aqueous solution of acetic acid (3 mmol/L) and potassium hydroxide (2.25 mmol/L) is used as an elution, and the wavelength of an absorbance detector is fixed at 220 nm.

3. Results and discussion

Table 1 shows H_2O_2 concentration in the sampled water after the exposure of the plasma jet. H_2O_2 concentration tends to increase with the exposure of Ar/H_2O plasma jet and the increase of H_2O concentration in Ar gas, but H_2O_2 is not detected after the exposure of Ar plasma jet; therefore, there are few OH radicals produced by the dissociative collision of H_2O in deionised water with excited Ar atom produced by the plasma jet. Furthermore, the addition of H_2O to Ar gas leads to the increase of the concentration of OH radicals produced by the plasma jet.

References

(1) S. Hamaguchi: J. Plasma Fusion Res., **87**, 10 (2011) 696
(2) D. Shibahara *et al.*: J. Inst. Electrostat. Jpn., **34**, 1 (2010) 2
(3) N. Takeuchi *et al.*: Proc. of the 74th JSAP Autumn Meeting, 19p-C2-9 (2013) 08-133

Table 1. H_2O_2 concentration in the sampled water after exposure of plasma jet

exposure time [min]	H_2O_2 concentration [ppm]		
	Ar (RH 0%)	Ar/H_2O (RH 8%)	Ar/H_2O (RH 14%)
0	0	0	0
3	N.D.	N.D.	0.97
6	N.D.	0.67	1.77
9	N.D.	0.99	3.00
12	N.D.	1.27	5.39
15	N.D.	1.55	7.04

*detection limit: 0.6 ppm