2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

Agricaltual Application of Gas-liquid Interface Reaction of Dinitrogen Pentoxide Generated by Atmospheric Air Plasma

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Recent years, effects of atmospheric pressure air plasma jet (APAPJ) have been experimentally examined for life science applications where the unavoidable gas/liquid interface exists. It has been found that one of the key features of APAPJ is to produce reactive oxygen/nitrogen species (RONS) in the liquid phase. Especially, usage of the plasma effluent gas is the key for plasma agricultural applications which require scalable and cost-effective plasma sources to use in a vast farming field. The air plasma effluent usage for sterilization and plant disease management [1] has been suggested. Through the dissolution of the plasma effluent gas into the liquid phase, RONS may change its form and could be involved in productions of short-lived RNS such as $HOONO_{aq}$ and HO_2NO_{2aq} [2, 3], whose roles and formation processes have not been completely explained yet. Therefore, in this work, the formation of the plasma generated RONS and short-lived RONS in liquid phase is studied with optical absorption spectroscopy, chemical probes, and Fourier Transform Infrared spectroscopy (FTIR).

Figure 1 shows the experimental apparatus for RONS flux measurement from the plasma effluent gas to 40 mL distilled water (DW). Variable flow rates of the air and liquid water can be supplied to atmospheric pressure DBD plasma, then all introduced water were vaporized under the present condition, owing to the discharge coupling power. The plasma effluent gas, composed from air and water, was suctioned into a flask with DW at 10 cm downstream from the DBD plasma, then the dissolved nitrate ($NO_3^-{}_{aq}$), nitrite ($NO_2^-{}_{aq}$), hydrogen peroxide (H_2O_{2aq}) were measured. These species fluxes were monotonically increased with the water flow rate (F_{H2O}) into the DBD plasma. The increase of those species flux indicates the productions of the $HOONO_{aq}$ in the air plasma effluent exposed solution, if the solution pH is sufficiently low typically below 3.4.

NiSPY-3 solution in 10 mM phosphate buffer at pH 7.2 is used to show histochemical production of $ONOO^-{}_{aq}$, which is the conjugate base of $HOONO_{aq}$. NiSPY-3 can be nitrated by $ONOO^-{}_{aq}$ and converted into NiSPY-3N, which is a fluorescent substance. Significant NiSPY-3N fluorescent was observed during the plasma effluent exposure without significant pH drop. This might indicate the $HOONO_{aq}$ production in the gas-liquid interface, where the solution pH could be significantly lower than the bulk pH, then the produced $HOONO_{aq}$ might be dissociated into $ONOO^-{}_{aq}$. Figure 2 shows the effect of the water flow rate (F_{H2O}) into the DBD plasma on the NiSPY-3N flux. While the $HOONO_{aq}$ reactants ($NO_2^-{}_{aq}$ and H_2O_{2aq}) tend to increase with F_{H2O} increase, NiSPY-3N flux decreases with F_{H2O}.

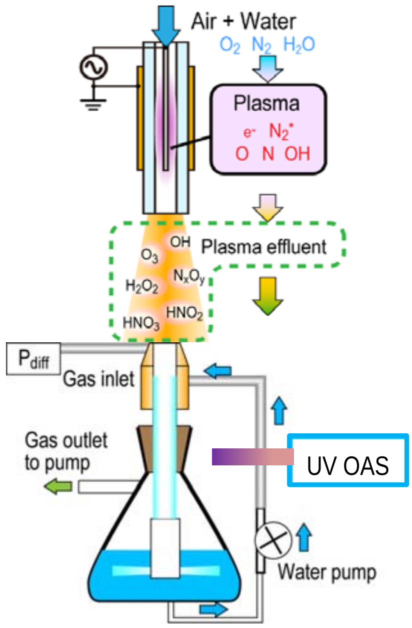

Figure 1. Experimental apparatus for APAPJ exposure.

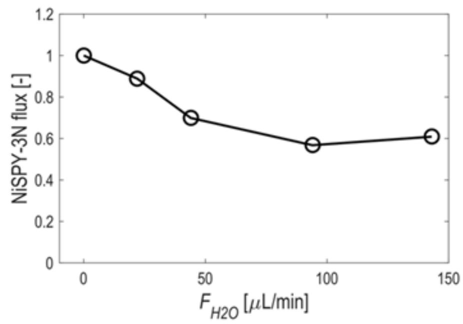

Figure 2. Effect of the water flow rate into the DBD plasma normalized NiSPY-3 flux.

Thus, the $HOONO_{aq}$ production in the gas-liquid interface does not dominate the nitration of NiSPY-3 into NiSPY-3N. This NiSPY-3N could be produced by the other nitration species from the plasma effluent such as dinitrogen pentoxide (N_2O_5). The N_2O_5 is known to be generated in the air plasma and often considered as the source of $NO_3^-{}_{aq}$. Further discussion and results on the gas-liquid interface reaction with plasma generated N_2O_5 and its agricultural application will be presented.

References

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