Gas-liquid interfacial plasmas: Controlled generation of short-lived reactive species and its applications

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Atmospheric pressure plasmas (APPs) in contact with liquid, which are defined as "gas-liquid interfacial plasmas (GLIPs)", are widely used in medical, agricultural, and public health fields. In these applications of GLIPs, the reactive species generated by the plasma in the gas and liquid phases, especially those with short lifetimes, are considered to play an important role (Fig. 1).

In this study, the controlled generation of short-lived reactive species using several lab-built GLIP devices and the elucidation of their chemical reaction mechanisms are realized [1,2], and applications such as sterilization [3], virus inactivation [4,5], cell membrane permeabilization (molecular transfer to biological cells) [6], and enhancement of plant immunity [7], using these short-lived reactive species are demonstrated.

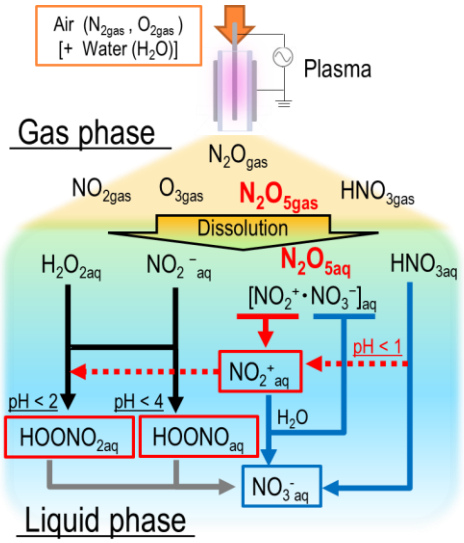

Fig. 1: Transport of reactive species generated by air plasma to the liquid phase and generation of short-lived reactive species in liquid.

In addition, GLIP experiments using high-speed liquid-column flow [8] are conducted to investigate in detail the spatio-temporal dynamics of the short-lived reactive species in the liquid phase irradiated by a helium plasma. As a result, very fast decay (a half-life of ~ 0.1 msec) of OH radical was detected for the first time and explained with a numerical model assuming surface-localization of OH radical.

Furthermore, we are trying to measure not only OH radicals but also short-lived reactive nitrogen species (RNS). To achieve this purpose, we attempted to measure short-lived RNS, which are precursors of long-lived RNS such as nitrate and nitrite, using a GLIP system equipped with a high-speed liquid column flow as shown in Fig. 2.

As a result, we have successfully measured the time decay of precursors of RNS using the reagent p-HPA (p-hydroxyphenylacetic acid), a scavenger of nitrite and nitrate precursors. The nitrite precursors were detected whereas nitrate precursors were below the detection limit, and the half-life of nitrite precursors was approximately 3 ms, which is obviously longer than 0.1 ms of OH.

These findings will contribute to the fully controlled generation of short-lived reactive species at the plasma-liquid interface, and the resulting selectively generated short-lived reactive species will be extended to a wide range of applications in environmental science, plant science, drug discovery science, material science, and other fields.

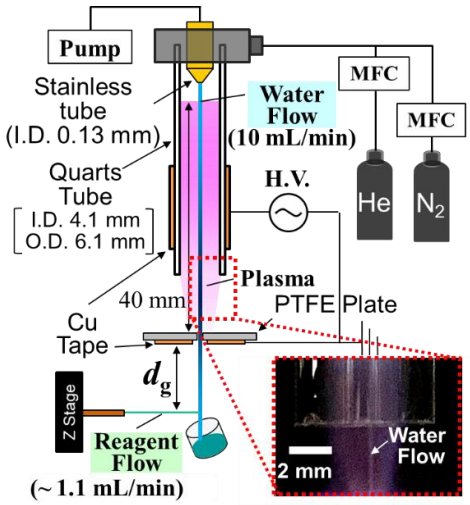

Fig. 2: Schematic drawing of the GLIP system with high-speed liquid-column flow.

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