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Plant pathogens control using air atmospheric pressure plasmas

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Atmospheric pressure plasma (APP) technology, enabling to convert air molecules into multi-functional reactive oxygen and nitrogen species (RONS), has been of great interest and extensively investigated. In particular, air APP devices, working only with air and electricity, can potentially allow for ubiquitous supply of RONS, which can be applied in a wide range of fields such as medical, agricultural, environmental, and biomaterial fields [1-4]. Recently, we have developed a new composite air APP device consisting low and high temperature plasma reactors, enabling to supply RONS [dinitrogen pentoxide (N_2O_5), ozone (O_3), nitric oxides (NO_x), …] with fine control and good reproducibility [5]. In addition, the APP device can utilize room air and renewable energy sources, such as a solar cell, and thus can realize sustainable and ubiquitous RONS supply.
Among the RONS synthesized by the air APP device, N_2O_5 is well known as a powerful oxidizing and nitrating agent and can potentially be bioactive. Since the air APP devices can easily supply N_2O_5 to biomaterials (e.g., amino acid, protein, cells, virus, bacteria, $\cdots$), we are exploring the inactivation effects of N_2O_5 exposure on pathogen and virus, modification of amino acid, and activation effects of plant immunity by the APP synthesized N_2O_5 gas (APP-N_2O_{5gas}).
First, we have investigated the inactivation effects on C. gloeosporioides (strawberry pathogen) and $Q\beta$ phage (RNA virus). The APP-N_2O_{5gas} exposure significantly increased the inactivation effect, which was not only due to pH decrease by HNO_{3aq} transfer into the droplet from N_2O_{5gas}. This indicates that N_2O_{5aq}, $[NO_2^+][NO_3^-]_{aq}$, or ${NO_2^+}_{aq}$ may contribute to the inactivation [1].
Second, we conducted experiments on the modification of amino acids such as tyrosine by APP-N_2O_{5gas}. Tyrosine solution was treated by N_2O_{5gas} together with several reactive species such as O_{3gas} or NO_{2gas}, and it is found that dopachrome and nitrotyrosine were generated by the modification of tyrosine [5]. Interestingly, dopachrome generation rate in N_2O_{5gas} with excess O_{3gas} was most high, and the dopachrome generation was correlated with O_{3gas} density.
Third, activation effects of plant immunity were found in pathogen inoculation test using Arabidopsis thaliana, exposed to APP-N_2O_{5gas} [6]. Gene expression analysis with RNA-seq and qRT-PCR showed that the N_2O_{5gas} exposure activated the signaling pathways for jasmonic acid (JA) and ethylene (ET), which are important phytohormones for plant immunity. These results indicate that N_2O_{5gas} can be used as a plant activator and also indicates that those N_2O_5 effects were pronounced when the plants were placed in high humidity conditions.
In the presentation, the details of the various biomaterial APP processes and APP-N_2O_{5gas} reaction pathway in the gas and liquid phase will be discussed.
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