Plasma Biology, Agriculture, and Environment Focus Topic
Room 104A - Session PB+BI+PC+PS-WeA

Plasma Agriculture & Environmental Applications

Moderator: Deborah O'Connell, University of York, UK

2:20pm **PB+BI+PC+PS-WeA1 Pulsed Power Applications for Farming and Food Processing**, ***Koichi Takaki,*** Iwate University, Japan **INVITED**

High-voltage and plasma are useful in several stages in agriculture, fishery and food processing including contribution to the food safety. Pulsed high-voltage produces intense high-electric field which can cause some biological effects such as stress response (stimulation) and electroporation. Types of pulsed power that also have biological effects are caused with gas discharges and water discharges which include reactive species such as ROS and RNS. We developed repetitively operated compact pulsed power generators with a moderate peak power for the agricultural applications.

The pulsed repetitive discharge were used for promoting growth of the vegetables and fruits. The growth rate of the vegetables and sugar content in the strawberry harvested after the cultivation increased by the plasma irradiation to the hydroponic solution [1] . The plasma was irradiated in the drainage water for 10 and 20 minutes each day. The leaf size of the plants increased with plasma treatment time. Number of colony forming units (CFU) of *R. solanacearum* in the liquid fertilizer decreased from 10^7 to 10^2 CFU/mL using the discharge plasma treatment [2]. Seedlings with discharge plasma treatment were relatively healthy; in contrast, all seedlings in the positive control wilted and died from infection of *R. solanacearum* after 12 days. The yielding rate of Shiitake mushroom (*L. edodes*) was also improved with the high-voltage stimulation in fruit-body formation phase [3] .

Electrostatics effect were used for keeping freshness of not only agricultural products [4, 5], but also marine products [6] . In postharvest phase of agriculture, keeping freshness in storage house and in transportation container is important. The electrostatic effects can contribute to remove airborne bacteria and fungi spore from the storage house and container [4] . This removal contributes to reduce the infection risk with fungi and bacteria. Some kinds of fruit and vegetable emit the ethylene gas which accelerate a degradation of other kind fruits and vegetables. The plasma can contribute the ethylene removal via oxidization reaction [5] . The AC electric field induces a conformational change of protein. This technologies can contribute to extend the freshness of marine products [6] .

References:

1. J. Takahata *et al.*, Jpn. J. Appl. Phys., **54** (2015) 01AG07.

2. T. Okumura *et al.,* Plasma Medicine, **6** (2017) 247.

3. K. Takaki *et al.*, Microorganisms, **2** (2014) 58.

4. S. Koide *et al.*, J. Electrostatics, **71** (2013) 734.

5. K. Takahashi *et al.,* J. Jpn. Appl. Phys., **57** (2018) AG04.

6. T. Okumura *et al.,* Jpn. J. Appl. Phys., **55** (2016) 07LG07.

3:00pm **PB+BI+PC+PS-WeA3 Stimulus Control on Organisms Using Pulsed Power Technology**, ***Douyan Wang,*** *T. Namihira,* Institute of Pulsed Power Science, Kumamoto University, Japan **INVITED**

Pulsed power is instantaneous ultra-high power with high energy density (10^5-10^7J/m^3). By controlling and utilizing it in a narrow space and an instantaneous time, phenomena and reactions that are not attained by conventional and ordinary methods can be achieved. For instance: electromagnetic field, discharge plasma, shockwaves, intense light emission, etc. By selecting or combining some of these physical phenomena, it is able to control the degree of output performance. Bioelectrics refers to the use of pulsed power, powerful pulsed electric or magnetic field for extremely short periods of time, non-thermal plasmas in gases or liquids and shock waves, in order to give novel physical stresses to biological cells, tissues and/or organisms as well as bacteria. Bioelectrics is an interdisciplinary academic field over physics, chemistry, biology, medical science, agriculture, environmental, mechanical and electrical engineering, and is expected to open up new science and technology.

By controlling the degree of electrical stimulations using pulsed power, it is possible to either inactivate biological targets or keep them alive and activate their functions. Examples of inactivation are given as: sterilization of liquids, treatment of algae and marine harmful organisms, growth inhibition of plants. On the other hand, more delicate stress control enables the activation of living organisms such as transcriptional activation of genes, substance transduction into cells, growth enhancement of plants. Both direct and indirect stimuli are useful. Here, aerial, liquidus and edaphic environmental control are examples of the indirect stimulus.

4:20pm **PB+BI+PC+PS-WeA7 Synthesis of Nitrates by Atmospheric Microplasma in Aqueous Solution**, ***Nicolas Maira,*** *F. Reniers,* Université Libre de Bruxelles, Belgium

For many years, cold atmospheric plasma techniques have been used for a large variety of applications such as surface modification, film deposition, nanoparticles synthesis or pollutants degradation. One of their main advantage is the possibility to work with a gaseous, liquid or solid phase. In this study, the plasma water treatment is investigated for a potential application in agriculture. When water solutions are treated by plasma, in air environment, several reactive oxygen and nitrogen species (RONS) are generated [1,2]. The main RONS are hydrogen peroxide (H_2O_2), nitrites (NO_2^-) and nitrates (NO_3^-). Nitrates are one of the most essential molecules for plants because, together with ammonium, they represent an important source of nitrogen which is mandatory for DNA, RNA, enzymes, chlorophyll, ATP and many other molecules. For some applications such as hydroponics or urban agriculture, the local production of pure nitrates fertilizers directly available in the flowing water feeding system would be of great interest.

In this study, a DC atmospheric microplasma system is used for the investigation of the formation mechanism of NO_3^- in water. The liquid phase is analyzed by Ionic Chromatography (IC), UV-visible spectrometry (UV-vis) and pH-metry, whereas the gas phase is probed by Optical Emission Spectroscopy (OES) and atmospheric Mass Spectrometry (MS).

Firstly, the influence of the inner diameter of the microplasma stainless steel needle is investigated (internal diameter of 0,76 mm, 0,50 mm and 0,20 mm). The amount of NO_x^- (NO_2^- and NO_3^-) synthesized varies with the diameter and the shape of the plasma is different for a larger internal diameter. Furthermore, the total amount of NO_x^- formed in a solution shows a linear trend with the total charge injected into the plasma with, however different slopes for nitrites and nitrates.

The oxidation mechanism of NO_2^- to NO_3^- is then explored and the influence of other reactive species on this mechanism is then studied. Indeed, it is known from the literature that H_2O_2 may play a role in the process for different atmospheric plasma systems [2]. The formation of oxygenated water and its role as an oxidant is highlighted in the microplasma system. Therefore, the amount of H_2O_2 synthesized by microplasma is compared to other plasma systems. The nature of the atmosphere above the solution is modified in order to determine the species formed in the gaseous phase and their respective influence.

The authors would like to thank the financial support of NITROPLASM (EOS Project 30505023)

[1] Machala Z. *et al. Plasma Processes and Polymers*, 10, 649-659, **2013**.

[2] Judée F. *et al. Water Research* 133, 47-59, **2018**.

5:00pm **PB+BI+PC+PS-WeA9 Design Considerations for Plasma-based Water Purification Reactor Scale-up**, ***John Foster,*** *S.M. Mujovic, J.R. Groele, J.C.Y. Lai,* The University of Michigan-Ann Arbor **INVITED**

Plasma-based water purification has been proven viable in laboratory demonstration experiments, highlighting its effectiveness at the removal of contaminants of emerging concern and at disinfection. While these small scale experiments bolster the promise of plasma based advanced oxidation, translating demonstration experiments to practice has proven challenging. A chief challenge is the scale up of plasma-based methods to a viable water treatment technology that is both robust and usable at treatment flow rates of interest. Presented here is an attempt to frame the scope of the challenge, the current state of the art in plasma water purification, and scale up design considerations both from plasma science and engineering standpoints. The objective here is to summarize key challenges to scale-up and implementation as well as elaborate on approaches to achieving a high throughput plasma-based water treatment system. Two illustrative reactor examples amenable to scale up are highlighted along with associated performance data. The pathway from bench-top demonstration of plasma-based systems to piloting and ultimately to the reduction of the technology to practice is also elaborated upon.

5:40pm **PB+BI+PC+PS-WeA11 Radicals and Ozone Generated in Ar/He and Ar/He/H_2O Plasma by using Atmospheric Pressure Plasma Jet Systems and their use in Methylene Blue Degradation***, J.H. Hsieh,* ***YiJinWei Wei****,* Ming Chi University of Technology, Taiwan, Republic of China*; C. Li,* National Yang Ming University, Taiwan, Republic of China

Optical emission spectroscopy (OES) and UV absorption spectrometry were first used to gather information about the excited species present near/in the plasma plume generated using Ar/He and Ar/He/H_2O gases with an atmospheric pressure plasma jet (APPJ). Afterward, the APPJ system was used to study its efficiency in degrading methylene blue as a function of radical and ozone density. According to the results, it was found that the degradation of methylene blue was directly related to the ozone concentration and, perhaps, OH radical density. Additional moisture may be used to control the ratio of ozone and OH radical density, resulting in the variation of degradation rate. Complete degradation of MB can be achieved in 80 seconds.

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