Pulsed Power Agriculture; Design of Pulsed Power Generator and Its Applications in Agriculture and Food Processing

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Abstract: Pulsed power technologies, including pulsed electric fields (PEFs) and time-modulated plasmas, have been applied in agriculture and food processing. The compact pulsed power generators have been developed and used in the applications such as seed germination, seedling growth, fruit body formation, keeping quality of agro-products, and in food processing such as drying, pasteurization, permeabilization of agro-products.

1. Introduction

The pulsed power technologies are actively utilized in applications of agriculture and food processing [1]. In the applications, compact pulsed power generators (PPGs) with moderate peak power and repetitive operation are developed for controlling discharge plasmas and electric field distribution. The applications are mainly based on the biological effects of a spatially distributed electric field and of chemically active species in the plasma. The agro-applications are categorized as two phases: preharvest and postharvest. The preharvest phase consists of seed germination, seedling growth and growth mode change from vegetative to reproductive. The postharvest phase consists of storing the products and food processing such as drying, pasteurization and permeabilization.

2. Design of pulsed power generator

One of key issue for agro-application using intense electric field is production of multi-reaction field of plasma and intense electric field with spatially and temporally control to adapt whole bio-scale as shown in **Fig. 1**. The pulse width of the intense electric field is designed to match relaxation time. The PPG is also designed to match temporally changed impedance of bio-specimen by choosing PPGs system for optimization to the biological load. The power semiconductor switching devise such as SiC-MOSFET are useful in compact PPGs for repetitive operation and low energy loss [2].

3. Applications in agriculture and food processing

In the preharvest phase, there are two approaches for plant growth enhancement. One approach is direct stimuli of plant tissues using intense electric field [1]. The other is indirect stimuli in which intense electric fields (including plasmas) are exposed into the bed medium used in plant cultivation. Moreover, the electrical stimuli can also be used for promotion of plant growth mode change from vegetative to reproductive. The mushrooms are mainly belonged to basidiomycetous fungi, and some are ascomycetous fungi, thereby, mushrooms commonly form spore at reproductive growth phase. Proper control of applied electrical energy can cause physical stimulus to the mushroom mycelium in the cultivation environment, resulting in promotion of fruiting body formation for increasing harvest yield [2].

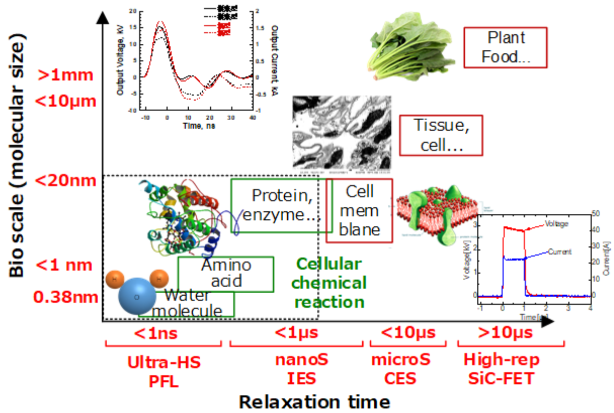

Fig. 1. Relation between bio-scale and relaxation time for design of pulsed power system.

Keeping freshness of agricultural products such as fruits and vegetables in food supply chain is important topic in the aspects of building a sustainable society. The main factors of quality deterioration are respiration and spoilage driven by ethylene (C_2H_4) and microbial contamination. The radicals produced by atmospheric non-thermal plasma, which has a high chemical oxidation potential, can contribute to rapid decomposition of C_2H_4 and inactivation of microorganisms [3]. The PEF treatment is also used to extract health-promoting agents from vegetable or fruits, to improve drying process of agro-products, and to reduce enzyme activity in food processes [4].

Acknowledgement

This work was supported by a Grant-in-Aid for Scientific Research Foundations S (19H05611) of JSPS.

References

[1] K. Takaki, *et al.*, J. Phys. D, **52**, 473001-1-42 (2019).
[2] K. Takaki, *et al.*, Rev. Modern Plasma Phys., **5**, 12-1-112 (2021).
[3] K. Takaki, *et al.*, Jpn. J. Appl. Phys., **60**, 010501-1-13 (2020).
[4] K. Takaki, *et al.*, Molecules, **26**, 6288-1-31 (2021).