【Grant-in-Aid for Transformative Research Areas（A）】

# Plasma-driven Seed Memory Operation: Frontiers in Molecular Dynamics in Seeds driven by Plasma


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| Project Information | Project Number : 24A206　　Project Period (FY) : 2024-2028<br>Keywords : Plasma, Reactive Species, Epigenetics, Seeds, Plants |


## Purpose and Background of the Research

**●Outline of the Research**

Plasma converts external electrical energy into electron kinetic energy, producing light, ions, and chemically active molecules (reactive species: RS) through electron collision with atoms/molecules. In the early 2010s, the PI discovered that seeds irradiated with low-temperature plasmas showed growth promotion. Subsequently, in collaboration with seed scientists, we found that three minutes of air plasma irradiation to seeds can recover the damage caused by high temperature through alteration in the DNA methylation that turned gene expression on and off. To clarify the mechanism of the alteration by plasma irradiation, the PI aims to establish a new scientific area of plasma seed science based on the combination of physics, chemistry, and molecular biology. The establishment will lead to the creation of novel molecular biological analysis methods and revolutionize food production.

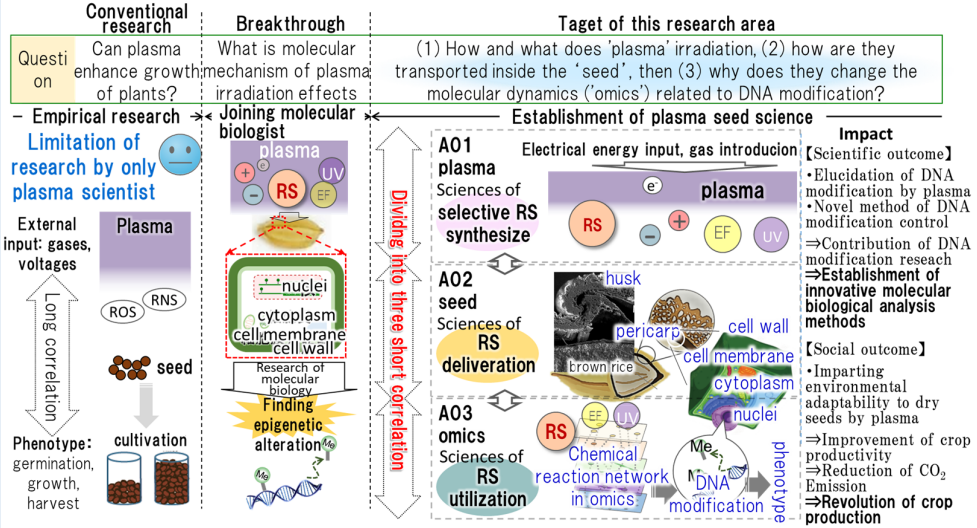


Figure 1. Overview of establishment of plasma seed science

**●What is omics?**

Omics refers to the comprehensive study of molecular dynamics in living organisms based on the chemical reaction network. It includes transomics (nucleic acids (genomics), DNA modifications (epigenomics), transcriptomics (transcriptomic), proteins (proteomics), metabolites (metabolomics)) related to the central dogma of genes, and also covers interactions (interactomics) and phenotypes (phenomics).

**●The seed stores memory of the stimuli received by the ancestor**

Plants have difficulty moving from where they are rooted, so they have a high adaptive capacity to climate change. They are stored as a memory in the DNA modification of seeds and passed on to the next generation. Parental generations stressed by high temperatures result in deteriorated quality of seeds (Fig. 2).

**●Low-temperature plasma irradiation selectively alters memory lying in seeds**

Low-temperature plasma is characterized by its ability to irradiate reactive species at high flux without damage. It has been shown that plasma irradiation to the temperature-damaged seeds result in selective changes in DNA methylation towards growth (Fig. 2). These results suggest that plasma irradiation for short time scale can selectively modify memories stored in seeds.

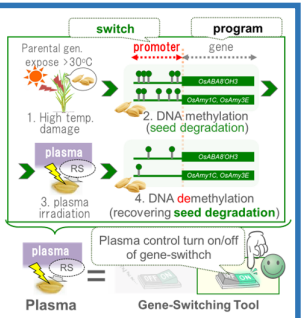


Figure 2. DNA modification by plasma irradiation

## Expected Research Achievements

**●Research strategy**

The basic strategy of this research is to create the academic field of 'plasma seed science' by unravelling scientific questions through the fusion of plasma science and seed science. To answer the questions, we set the keywords 'plasma', 'seed', and 'omics' as research items. The three research items will be integrated in the second half of the project period.

**A01 'Plasma':** The atmospheric pressure plasmas have two black boxes (Fig. 3). we will clarify the black boxes and establish the process model here. Based on this knowledge, a new plasma irradiation method with high selectivity will be created.

**A02 'Seeds':** Transport of reactive species generated by plasmas in nano-porous structure like cellulose, channels, and lipid membrane will be studied. Additionally, the generation of RS due to secondary reaction in seeds will also be clarified. (Fig. 4)

**Group A03 'Omics':** Conventional studies have mapped the chemical reaction as dots in omics network. Here, we aim to connect these dots to reveal the full picture of omics, focusing on DNA modifications in the rice genome. (Fig. 5)

In our research area, we will construct physical and chemical reaction network models based on the findings from the above three research targets.

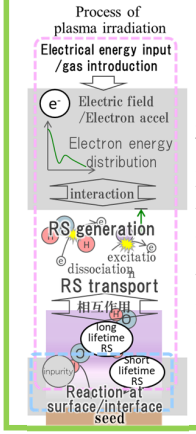


Figure 3. Expected achievements in A01. To establish the science from the formation of electric field and electron acceleration to the production and transport of reactive species (RSs) by external input of molecular gas plasmas and to realize the selective irradiation of RSs.

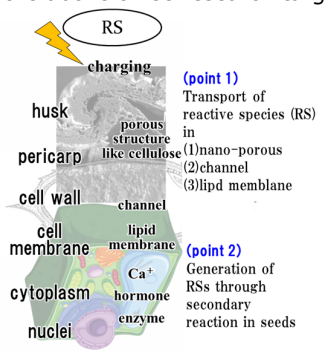


Figure 4. Expected achievements in A02. A full picture of plasma-driven transport in seeds will be provided.

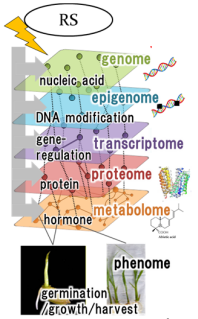


Figure 5. Expected achievements in A03. Process of DNA modification in omics will be elucidated.

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| Homepage Address, etc. | https://plasma.ed.kyushu-u.ac.jp/plasma-seed-science/en/ |