Study on changes in surface condition of plant seeds irradiated by atmospheric pressure gliding arc discharge plasma

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Abstract: In recent years, there have been numerous publications on plasma treatment of seeds in the agricultural field. Most of these studies have used atmospheric pressure plasma, and most of them have used dielectric barrier discharge (DBD). However, DBD is a high-voltage, low-current type of discharge and is not suitable for large-scale treatment of large quantities when practical application in the agricultural field is targeted. Atmospheric pressure gliding arc discharge (GAD) is a very attractive discharge type and will be expected to be applied to the agricultural field because of its simple configuration and large power consumption. This study investigated the surface of seeds irradiated with GAD plasma, as well as the modification of seed cross-sections, using SEM measurements. The images of seed cross-sections showed clear changes due to plasma treatment.

Keywords: Gliding Arc Discharge, seed treatment, plasma agriculture, SEM & EDS mapping

1. Introduction

Gliding arc discharge (GAD) is a very attractive discharge[1-4]. However, its non-thermal equilibrium and non-steady-state make its application a difficult task. In fact, although many papers have been published in the field of exhaust gas treatment, incomplete treatment due to the intermittent character of the discharge is still difficult to solve. On the other hand, agricultural applications of plasma technology have been actively studied in recent years, and numerous papers have been published. In particular, many papers have been published on the germination and growth promotion of seeds by plasma treatment. In many cases, the treatment was based on dielectric barrier discharge (DBD). However, DBD is expensive for large scale surfaces, and it is not easy to obtain large power consumption. On the other hand, we have been studying power control for GAD, and have shown that even kW-order devices can be made extremely compact size. Plasma applications in agriculture require low initial and operating costs, and maintainability is also an important factor. Non-thermal equilibrium and non-steady-state properties are not a problem in seed treatment. We have previously investigated the changes in seed surface conditions induced by GAD plasma irradiation, such as changes in water repellency and changes in seed water absorption characteristics. In this study, seeds were treated with multiple gas species in a single-phase DAG system, and the surface and cross-sectional conditions of the seeds were observed using a scanning electron microscope (SEM) (HITACHI Miniscope TM4000), and elemental composition analysis was carried out using EDS.

2. Experimental Setup

Fig. 1 shows the gliding arc discharge system used in this study. Although the figure shows argon gas as the introduced gas, three different gases were used in this study: argon (Ar), argon (Ar) + oxygen (O_2), and nitrogen (N_2). The seeds were placed on a rotating sample holder to ensure uniformity of plasma irradiation. Iron was used for the electrodes. Gas flow rates were maintained at 20 l/min for all gases. The mixing ratio of Ar to O_2 was 5:1. Three different positions of the discharge electrode and sample holder were used, and irradiation durations from 30 to 180 seconds were used. Pumpkins were used as seeds in this study. Because pumpkin seeds are relatively flat, only one side of the pumpkin seed was exposed to plasma irradiation. High-voltage probes and current probes were used to monitor the discharge to ensure its stability. Thermocouple thermometers were installed in the seed holders to measure the temperature rise during discharge.

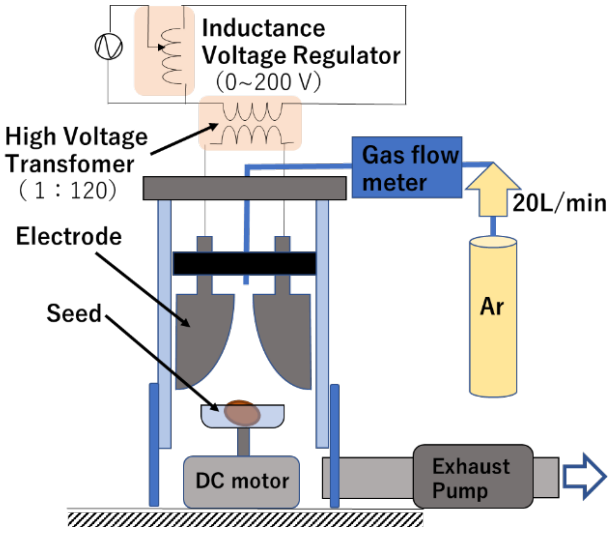

Fig. 1. Gliding arc discharge system

3. Seed handling and measuring methods

Pumpkin is a fruit vegetable belonging to the Cucurbitaceae family and is covered with a hard shell. Although there are many varieties of pumpkins, the seeds generally available on the market are not seeds of the same fruit, so seeds were removed from a single pumpkin in this study to ensure homogeneity. The removed seeds were washed in water and dried. Upon drying, a thin film on cellulose peels off from the seed surface. In this study, that thin film was removed from the seeds. SEM measurements were carried out to capture the surface conditions of the plasma-irradiated and non-irradiated surfaces, as well as the cross-section of the seed as it was cut.

4. Results

Fig. 2 shows cross-sectional SEM image of seed treatment in the introducing of N_2 gas and SEM images of plasma-irradiated and non-plasma-irradiated surfaces (Fig.3 (a), (b)). The plasma-irradiated surface showed more differences in the dense texture, which was distinct from the inside of the surface hard shell (about 50 μm) to about 300 μm.

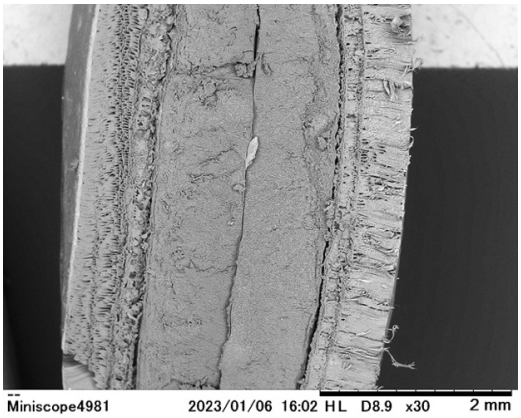

Fig. 2. Cross-sectional image of pumpkin seed

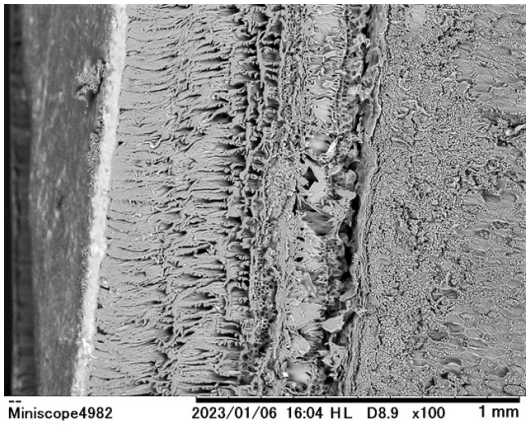

Fig. 3(a). Image of plasma irradiated surface

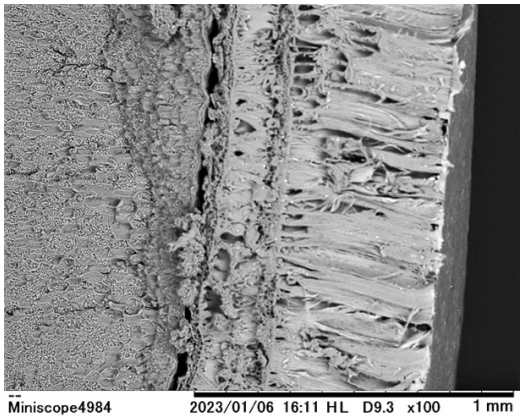

Fig. 3(b). Image of non plasma irradiated surface

The sparse tissue just below the seed surface is considered to be due to plasma irradiation. There were no significant differences in cross-sectional conditions by gas species.The surface reaction is obviously different between Ar and N_2 gas irradiation and the introducing of O_2, although more detailed measurements will be needed in the future to determine the difference in gas types. In other words, the oxidation of the seed surface should be accelerated by the oxygen plasma irradiation. In this study, a gas mixture with Ar was used, because in GAD, the discharge was not stable with 100% O_2. But the knowledge obtained from the cross-sectional observation was consistent with our previous report on the change in wettability due to plasma irradiation, that was the change in surface hydrophilicity and water absorption properties(The time of the first water absorption that is physical water absorption, of the water absorption characteristics of the seeds was accelerated) due to plasma irradiation.

5. Conclusion

Pumpkin seeds were irradiated with atmospheric pressure GAD plasma. SEM measurements showed clear differences in the surface and cross-section of the irradiated seeds. This result dictated the characteristics of wettability and water absorption properties identified in previous studies. EDS measurements and mapping of seed surface and internals were not shown in this abstract.

6. References

[1] S. Aoqui, et al. 2017 International Conference on Electromagnetic Devices and Processes in Environment Protection with Seminar Applications of Superconductors, ELMECO and AoS (2017)
[2] S. Aoqui, et al. Proceedings - 2015 IIAI 4th International Congress on Advanced Applied Informatics, IIAI-AAI (2015)
[3] S. Aoqui, et al. Physics Procedia 85 (2016)
[4] S. Aoqui, et al. IEEE Transactions on Plasma Science 44(12),7506230 (2016)