

# Application of low-temperature plasma technology in the field of agriculture

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**Abstract.** The low-temperature plasma crop seed treatment technology has opened up a new way for the application of plasma in crops, creating a new path for high and stable yield of crops, and enriching agricultural yield increasing technology. This article briefly describes the innovative development of low-temperature plasma seed treatment technology, introduces the series of applications of plasma technology in crop seeds, as well as the biological effects and activation mechanisms of plasma. It also looks forward to the development and application prospects of plasma seed treatment technology.

**Keywords:** Plasma, Agricultural processing, Discharge technology, Dynamism.

## 1. Introduction

Low temperature plasma is usually a high-energy aggregation state generated by gas discharge ionization, which contains a large number of active particles such as electrons, ions, photons, excited molecular atoms, and free radicals[1]. Low temperature plasma is currently one of the hotspots in physics research, widely used in electronics, chemical engineering, and medicine. Plasma crop seed treatment technology is the latest agricultural yield increasing technology developed internationally, and is the application of physical technology in the fields of biology and agriculture. This technology originated from space science, and most of the crop seeds carried by space launches exhibit abnormal growth vitality. Based on this inspiration, the Russian National Institute of Physics was the first to develop a plasma seed processing equipment that simulates the state of the space ionosphere. Various factors such as gas ions (plasma), radiation, electromagnetic fields, vacuum, etc. jointly act on crop seeds, stimulating their physiological activity and potential stress resistance gene expression, improving crop vitality and drought and cold resistance, and achieving good results. The United States, Ukraine, Israel, and South Korea have also studied and applied this technology. In addition, countries such as the United States and Canada have also studied low-temperature plasma treatment to sterilize and disinfect seeds for easy storage. The research on low-temperature plasma seed treatment technology has taken the lead in China, completing the entire process from equipment development, treatment dose determination, biological effect experiments, physiological mechanism exploration, and demonstration application, forming a practical series of technologies for increasing crop yield through plasma seed treatment[2-5].

## 2. Research on low-temperature plasma technology

### 2.1. Low temperature plasma seed processing technology

In recent years, agricultural researchers in China have also been continuously exploring low-temperature plasma seed treatment technology and achieved practical application results. Low temperature plasma seed processing technology is to place seeds in plasma, allowing them to come into contact with the plasma. Plasma is a high-energy aggregation state that can penetrate the seed epidermis and interact with the seeds, causing changes in some substances in the seeds, thereby stimulating crop yield.

To apply plasma to treat seeds, the first step is to obtain a stable plasma generator. The commonly used method is to ionize the air to form an air plasma, which is mainly composed of nitrogen and oxygen. In order to facilitate the ionization of the air, it is necessary to use very thin air, select an appropriate sealed container, and vacuum the sealed container. The so-called vacuum is a gas state below one atmospheric pressure, An atmospheric pressure is tens of thousands of pascals, and the vacuum used to generate plasma is generally around 100 pascals. The lower the pressure, the thinner the air and the higher the vacuum. In this sealed container, two electrodes must also be installed, which can be composed of two conductive parallel plates. Similar to a parallel plate capacitor, the electrodes are connected to the outside world through wires and connected to a qualified power supply. When the vacuum of the container reaches around 100 pascals, When the power is turned on and a certain voltage is applied, the air between the two parallel plate electrodes in the vacuum container is ionized, forming an air plasma. The air plasma is mainly composed of nitrogen ions, oxygen ions, and electrons between the two plates. Generally, substances in the plasma state are often accompanied by glow discharge phenomena, which is the basic principle of a plasma generator. With a plasma generator, the seeds of crops are placed in a vacuum container between two plates in a certain way, allowing the plasma between the plates to come into contact with the seeds. Through a certain amount of time and intensity of plasma treatment, the activity of the seeds can be improved, achieving the goal of increasing crop yield in production.

## **2.2. Innovative Development of Low Temperature Plasma Treatment Technology**

One of the most important accessories in low-temperature plasma equipment is the discharge power supply that generates plasma through gas discharge. The commonly used power supply can be classified according to frequency: DC power supply, low-frequency power supply, RF power supply, and microwave power supply. If a DC power supply is used, a current limiting resistor is required to prevent the formation of an arc. The resistance value of the current limiting resistor needs to be changed for different gases and working conditions, making it difficult to regulate, and the current limiting resistor itself also consumes electrical power; For low-frequency power sources: due to the low excitation frequency, long alternating period, and longer time than the existence of plasma, the plasma darkens or extinguishes in every half cycle, which is extremely unstable; Although microwave power supplies have high frequency, stable plasma, and high reaction activity, they are not only expensive for large volume plasma reaction chambers, but also difficult to obtain uniform plasma. Therefore, in low-pressure glow discharge that generates plasma, RF power is usually used. The principle of using a power source for plasma seed processing equipment is to enable the active particles in the plasma to obtain as much energy as possible under the action of an electric field, and to exchange energy with each other, especially in the event of inelastic collisions. The frequency of the RF power supply commonly used in plasma modification equipment for low-pressure glow discharge is 13.56 MHz. Due to its high frequency, electrons oscillate back and forth in a fast alternating electric field, constantly accelerating their motion to obtain more energy from the electric field and convert its energy to other particles, generating new particles and photons. Under the action of such a high-frequency electric field, the extinction time of active particles in the plasma is much longer than the half cycle time of excitation, so the plasma is very stable and the reaction activity is also very strong. In addition, the two electrodes introduced by the RF power supply only generate a rapidly changing alternating strong electric field, providing electrons with energy in the electric field, rather than having conductive current passing through (even in the case of a glass reaction chamber, it can be discharged without electrodes). Therefore, the electrodes themselves do not overheat excessively. At the same time, regardless of the size of the plasma reaction chamber, a uniform plasma working area can be obtained using a radio frequency power supply.

## **2.3. Capacitive Coupled RF Glow Discharge Technology**

The use of radio frequency power supply and capacitance coupled electrode structure in glow discharge, combined with suspended electrode and shielded electric field technologies, can avoid

power loss and carry out low-temperature plasma diagnosis analysis, which is conducive to the concentration of low-temperature plasma energy and the effectiveness of green treatment.

Based on the improvement of discharge technology, we have mastered the key technology of low-temperature plasma capacitance coupling discharge. The use of RF power supply in discharge, combined with suspended electrodes and shielded electric field technology, is conducive to energy concentration in the discharge area, reducing power loss, and achieving processing with smaller power. Exploring the physiological effects of low-temperature plasma green treatment by studying the mechanism of low-temperature plasma treatment.

The research and development of low-temperature plasma seed treatment equipment is also receiving increasing attention. The low-temperature plasma treatment technology was first commercialized in Russia, and relevant domestic departments and units have also introduced some plasma modification treatment equipment from abroad. However, it has also been found that there are significant shortcomings: the equipment has poor process repeatability and high energy consumption. After carefully studying the situation of foreign equipment, it was found that the fundamental flaw was that the discharge technology of the equipment was not properly handled, which resulted in serious DC discharge phenomenon in the RF electric field. The fundamental reason was due to electrode asymmetry. In the RF alternating electric field (13.56MHz), due to the metal cylinder participating in one electrode (ground) discharging the other electrode (target), a large amount of charge could not be released, forming a DC potential, This results in a low effective power of the RF electric field and poor process repeatability. There are also technologies in China that use RF sources to connect two parallel electrode plates to generate glow discharge zones. However, due to the fact that glow discharge occurs between the two electrode plates and the inner wall of the cavity, power consumption increases sharply and energy is wasted, and a concentrated glow discharge zone cannot be generated between the two electrode plates. The suspension shielding method of RF glow discharge is shown in Figure 1.

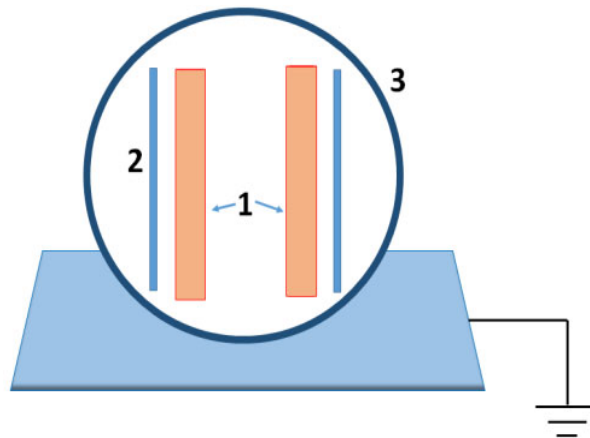


Fig.1 Suspension shielding method

(1-pair of electrodes; 2-metal plates; 3-grounded shells)

This project aims to address the shortage of foreign equipment and master key technologies. It adopts radio frequency power supply, combined with suspended electrodes and shielded electric field technology, which is conducive to energy concentration in the discharge area. After carefully studying the situation of foreign equipment, it was found that the fundamental flaw was that the discharge technology of the equipment was not properly handled, which resulted in severe direct current discharge in the RF electric field. The root cause was due to electrode asymmetry. In the RF alternating electric field (13.56MHz), the metal cylinder was involved in discharging one electrode (ground) to another electrode (target). A large amount of charge cannot be released, resulting in the formation of a direct current potential, which generates ion bombardment and consumes most of the

power, resulting in a low effective power of the radio frequency electric field, resulting in weak energy and inability to fully meet the process repeatability requirements.

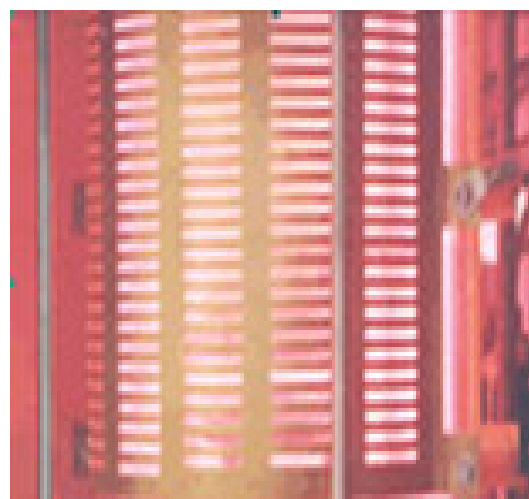
At the same time, strengthen the control and optimization of green treatment parameters. Control and improvement of vacuum system, trial production of processing system according to different process requirements in application fields, optimization of process parameters such as RF power supply, discharge power, source gas type and flow rate, etc., to achieve effective technical control.

#### 2.4. Development of low-temperature plasma seed processing equipment

Low temperature plasma seed processing equipment is a brand new technology in China. Drawing on Russian technology, plasma seed activation processing equipment has been developed, filling a gap in China. The plasma seed activation processing equipment mainly consists of three parts: radio frequency matching device, vacuum system, plasma generation device, and transmission system. Main technical indicators: The volume of the working vacuum chamber is  $\varphi 260\text{mm} \times 1200\text{mm}$ , the pressure at which plasma is generated is  $30\text{Pa}-1 \times 10^5\text{Pa}$ , working voltage 380V, frequency 50HZ, power 50-1000W, and discharge method is glow discharge. The diagrams of glow discharge with radio frequency plasma are shown in Figure 2.



(a) continual surface treater



(b) steady state surface treater

Fig.2 Diagrams of glow discharge with radio frequency plasma

### 3. Study on the Biological Effects and Activation Mechanism

For the mechanism of plasma seed treatment, a preliminary explanation can be made through experiments. A comparative experiment is conducted on a certain variety of wheat. Wheat treated with plasma and untreated wheat are cultivated in a culture dish under the same conditions. After one week, one gram of germinated seedlings are taken from each dish, placed in a mortar, ground into a uniform slurry, poured into a measuring cylinder, diluted to a certain proportion, and then separated by a centrifuge, Take the supernatant as a backup. Since various enzymes in the substrate are dissolved in the supernatant, the activity of certain enzymes in wheat seedlings can be measured using this supernatant through certain technical means. In the experiment, the activities of the following enzymes were tested: amylase (ATP), peroxidase (POD), and superoxide dismutase (SOD), which play an important role in crop growth, The experiment showed that the activity of these three enzymes significantly increased after a certain amount of plasma treatment on crops. The activity of enzymes related to plasma treatment increased by 60.6-143.1%, and the ATP content increased by 9.1-62.2%. Enzyme spectrum analysis showed that there was no change in the number of enzyme bands, but the enzyme activity was significantly enhanced. The ATP content in plant leaves increased by 13.9-178.5%, and the root system increased by about 7.5%. Under drought stress conditions, the accumulation of osmotic regulating substances in crop leaves and roots increased, and the activity of protective enzymes such as POD and SOD increased by 12.9-60.8%. This reflects the promoting effect of plasma on seed germination and crop growth, and significantly enhances drought resistance.

### 4. Conclusion

Plasma is one of the current hotspots in physics research, and its development and application in the fields of biology and agriculture have only just begun internationally. Further research is needed on the mechanism of low-temperature plasma seed treatment, but its significant effects in crop yield and stress resistance are obvious. Low temperature plasma technology uses industrial production to promote agricultural yield increase, It is a revolutionary new technology for increasing agricultural production. The application of plasma seed treatment technology in agricultural production has the advantages of one-time investment, long-term benefits, low operating costs, no variation, no pollution, significant yield increase, and strong practicality. To make the vast majority of farmers accept this new agricultural technology, it requires a process of increasing publicity efforts, as well as a certain amount of funding and technical investment. Equipment should be further improved and standardized as soon as possible to achieve mass and commercial production, strengthen promotion efforts, expand application scale, and create greater economic and social benefits. The promotion of this technology will undoubtedly have a significant impact on the modernization of agricultural equipment.

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