Effect of the Corona Discharge on Peel Microstructure

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***Abstract*—To better understand the biological effects of high-voltage corona field, expanding the application and study a new means of mutation breeding. A new experimental device which can produce the high-voltage corona electric field is developed. The design parameters and the electric field characteristics of the device are measured and analyzed. whether positive or negative corona discharge, the corona discharge current of the plate is increased with the applied voltage increasing; the voltage range of negative corona discharge is wider than that of the positive corona discharge, meanwhile under the same applied voltage, the negative corona discharge current is bigger, not only its curve is smooth, but also its discharge is stable. When the voltage is lower than 20kV the temperature increase linearly; after the voltage beyond 20kV the temperature is basically stabilizing, and it is about 10 ℃ higher than the room temperature, which shows that the thermal effect of electric field is small. The tip discharge current at the sample location under the action of pulse electric field is known to be about 10μA. The electric field strength is 7.0 kV·cm^{-1}.By atomic force microscope, It is found that under the negative corona electric field the surface of peel becomes hole and the diameter of the hole is about 1μm. The hole can be observed under the different electric field processing time (20 ~ 150 min). The developed device can produce a good high-voltage corona discharge. The voltage range of the positive corona discharge is narrow, while the voltage range of the negative corona discharge is wide and stable. In addition, the thermal effect produced by the high-voltage corona electric field on the sample is very small, so usually it can be ignored. The high-voltage corona electric field can change the surface morphology of some films, which shows that the effect of the corona electric field makes the current density of the sample location very large in a small cross section. In conclusion, the negative high-voltage corona discharge should well be used to research in biophysics such as the transgenic plants. High-voltage corona discharge mutagenesis has become a new physical mutation technique.**

Keywords- corona discharge; electric field characteristics ; peel; atomic force microscope

I. INTRODUCTION

Biomass energy is one of the important sustainable development energy resources, and its effective utilization will exert a great influence on solving energy and environmental problems. It is promising to make use of microbial technology in the field of new energy development. It has important theoretical and practical significance for sustainable development of energy. A quality variety of microorganism strains is directly related to the quality of industrial products. So it is necessary to cultivate microorganism strains of high-quality and high-yield. Microbe breeding is to apply genetic principles and techniques to reform some special productive strains and get rid of their harmful natures or add some beneficial characters. With its rapid development, breeding techniques have gene induce mutation, gene recombination, gene engineering and other modern methods. It has been widely used in microorganism breeding. At present, physical and chemical mutagenic technology are still used by domestic micro-organisms. The strains were treated by mutagen as action time increases, but the disadvantages are "fatigue effect", which leads to strain degeneration, growth cycle of bacteria was extended, lower spore number and lower cell growth. It is detrimental to the control of fermentation process. Therefore, the technology of new microbial mutation breeding has always been an important and urgent and challenging issue in breeding areas of microbial research. The GUS gene had been transferred into the callus by corona discharge[1,2,3]. To better understand the biological effects of high-voltage corona field, expanding the application and study a new means of mutation breeding. A new experimental device which can produce the high-voltage corona electric field is developed. In order to determine the appropriate field parameters, the positive and negative characteristics of high voltage electrostatic field were researched repeatedly. By atomic force microscope, It is studied that the surface of cell becomes hole and under the corona electric field.

II. THE DESIGN OF HIGH-VOLTAGE CORONA AND ELECTRIC FIELD CHARACTERISTICS

A. *Design of experimental device*

The developed experimental device is shown in figure 1. The voltage supplied by DC high voltage power can be continuously adjusted from 0 to 30 kV. In order to ensure the stability of discharge and high energy density of discharge, a lot of experiments are tried to find the best parameters. An ammeter whose resolution is 10 μA and accuracy is 0.8% is used to detect the discharge current, and a voltmeter is used to detect the applied voltage. The determined optimum parameters are the following: the distance between the adjacent needle plates is b = 20 mm, 18 needles are ranked in a line, the distance between the needle tips is $2c$ = 20 mm, and the tip

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diameter is $d < 0.01$mm. In this device the discharge medium is the air whose relative humidity is 25% ~ 40% and temperature is 20 ~ 25℃.

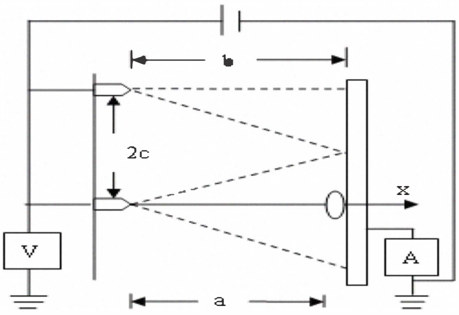

Fig 1. Schematic diagram of high-voltage corona discharge equipment

B. The parameters and field characteristics

1).The design parameters of high-voltage corona field

Many experimental results show that discharge was stability when the distance between the adjacent needle tip spacing is 20 mm and needle plates is 20 mm. At the same time discharge have high energy density. This is consistent with the conclusions that Wang Xiao-chen had researched[4]. The determined optimum parameters are the following: the distance between the adjacent needle tip spacing is 20 mm and needle plates is 20 mm and the tip diameter is d < 0.01mm.

2). V-A characteristics of high-voltage corona electric field

The measured V-A characteristics of positive and negative corona discharge between the adjacent needle plates are shown in Figure 2 and Figure 3 respectively.

From the figures 2 and 3 we can get: whether positive or negative corona discharge, the corona discharge current of the plate is increased with the applied voltage increasing; the voltage range of negative corona discharge is wider than that of the positive corona discharge, meanwhile under the same applied voltage, the negative corona discharge current is bigger, not only its curve is smooth, but also its discharge is stable. Because of the fact that when the tip electrode is the negative-discharge the repetition rate of discharge will increase[4], therefore, the negative corona discharge should be chosen in dealing with the sample. So the equipment presented here can be applied to the study of biological physics.

3).Relationship of voltage of high-voltage corona electric field and temperature between the plates

Set the Zero of the device at room temperature of 22℃ and measure the temperature on every 1kV; Wait for a minute after adjusting the voltage well, so as to achieve thermal equilibrium between the plates and then take pictures. Using the software the temperature of the selected region in the images can be obtained. The relation curve of voltage and temperature between the plates is shown in Figure 4. When the voltage is lower than 20kV the temperature increase linearly; after the voltage beyond 20kV the temperature is basically stabilizing, and it is about 10 ℃ higher than the room temperature, which shows that the thermal effect of electric field is small.

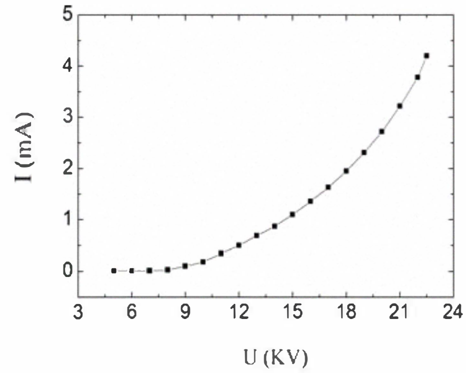

Fig2. Current-voltage characteristics of negative corona discharge

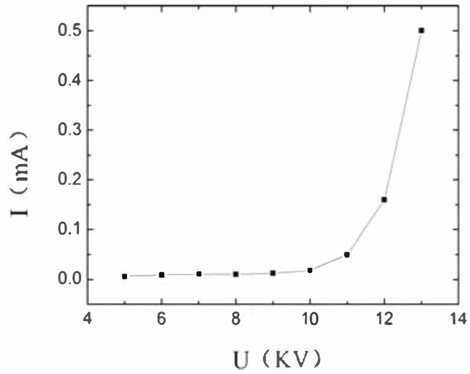

Fig3. Current-voltage characteristics of positive corona discharge

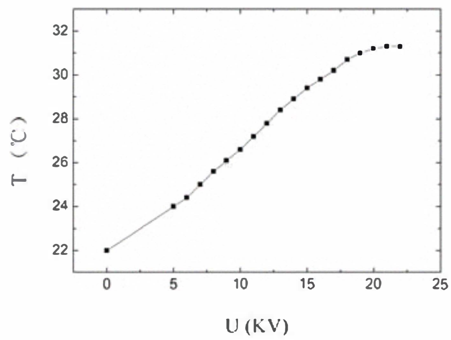

Fig.4 Relation curve between the voltage and the temperature

III. Effect of the Corona Discharge on Peel Microstructure

A. Materials

Look at the reference about the preparation of peel samples[5]. A medium size and no decay and mature apple was select. To take the peel and cut it into small pieces 9 mm^2 and they were placed on a slide to be observed.

B. Observations by atomic force microscope

Using Agilent 5500AFM/SPM, the peel surface is observed before and after the high-voltage corona electric field is affecting. The measuring conditions are: the room temperature; the humidity is 30% ~ 35%; the scanning range of AFM is 5μm × 5μm; the image resolution is 256 × 256; the probe is Si probe whose resonance frequency is 146-236 kHz and the force constant is 21 ~ 98 N•m-1.

IV. RESULT AND DISCUSSION

A. Cell electric perforation

The peel is first put under the AFM, then the parameters of needle height, gain, scanning pixels, etc. are adjusted, finally the scanning image of the morphology is shown in Figure 5. After the above steps the peel is placed in high-voltage corona electric field for treatment during 45min. The scanning image of the film after the action of the field is shown in Figure 6. From the two images we can conclude that: before the field affecting the deposition surface of peel is more dense and particles on the surface are smaller; after the effect the size of particles becomes large and uniform, and the surface of peel becomes hole and the diameter of the hole is about 1 μ m.

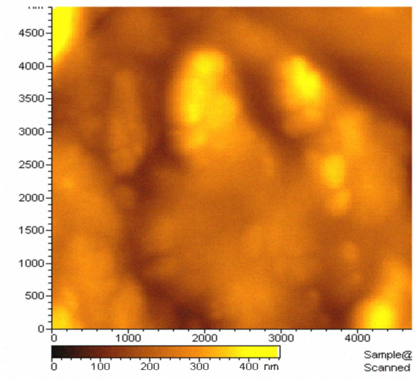

Fig.5 The AFM image of pre apple surface

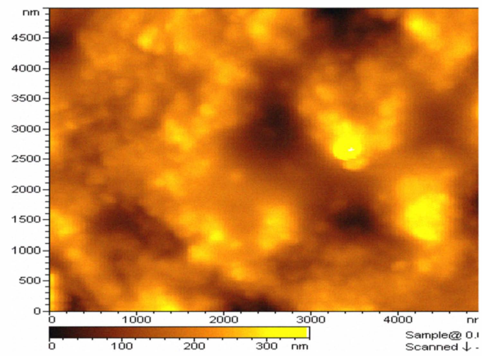

Fig.6 The AFM image of post apple surface

The peel was formed by the membrane. That hole was cell membranes were perforated. The hole can be observed under the different electric field processing time (20 ~ 150 min).

B. Electric field intensity and current density at the sample location

According to the needle-plate electric field distribution model we can estimate the electric field intensity at the sample location under the action of pulse electric field [6,7,8].

The field intensity distribution (between the electrodes) along the x axis in the corona electric field of multi-needle plates is:

$$E^2 = \frac{2Ib}{k\pi\varepsilon_0 c^2}\left[\frac{b}{a}+\frac{1}{\pi}-1\right], \qquad (1)$$

where E is the field strength, $\varepsilon_0 \approx 8.85 \times 10^{-12}$C/ (V· m) is the air-dielectric constant, $k = 2.1\times10^{-4}$m^2/ (V· s) is the negative ion mobility of dry air, I is the electric current of tip, b = 20mm is the distance between the tip and the plate, a = 9mm is the distance between the sample is the tip. According to the current intensity measured in the experiment, the tip discharge current is known to be about 10μA. Then from the Eq. (1) the electric field strength can be calculated as E = 7.0 kV·cm^{-1}. According to perforation diameter the cross-sectional area S of the space current should be less than 1 μm^2, so the current density is about 1×10^7A·m^{-2} because of $J=I/S$.

V. Conclusion

The developed device can produce a good high-voltage corona discharge. The voltage range of the positive corona discharge is narrow, while the voltage range of the negative corona discharge is wide and stable. In addition, the thermal effect produced by the high-voltage corona electric field on the sample is very small, so usually it can be ignored. The high-voltage corona electric field can change the surface morphology of some films, which shows that the effect of the corona electric field makes the current density of the sample location very large in a small cross section. In conclusion, the negative high-voltage corona discharge should well be used to research in biophysics such as the transgenic plants.

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