Improve the Discharge Efficiency of Atmospheric Pressure Plasma Jet by Changing Electrode Arrangement

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Abstract: The purpose of this study is to change the electrode arrangement of the atmospheric pressure plasma jet (APPJ) to improve its discharge efficiency. Compared with the previous research mainly discussing the electrode configuration of planer dielectric barrier discharge (DBD), this study designs high voltage electrodes with different geometric shapes and ground electrodes with different widths and positions, and observes the discharge performance and Reactive oxygen and nitrogen species (RONS) production of APPJ. This study uses optical and electrical measurement experiments, including Optical Emission Spectroscopy (OES), Lissajous figures, intensified charge-coupled device (ICCD), etc., in order to objectively observe the influence of different electrode structures on the plasma as much as possible. This research will discuss the geometric shapes of the high voltage electrode and the widths and positions of the ground electrode, and then combine the highest intensity parameters of the high voltage electrode and the ground electrode to design a APPJ with the best discharge efficiency and RONS production. The electrode structure design can be widely used in the field of plasma in the future.

Keywords: atmospheric pressure plasma, electrode configuration, electrode structure design.

1. Introduction

Atmospheric pressure plasma jet is a common atmospheric pressure plasma, which is more convenient to use in clinical treatment. Because it is a handheld design, it can be moved arbitrarily. A standard atmospheric pressure plasma jet usually includes a waveform input source, a dielectric layer, and a high voltage electrode and a ground electrode[1], so electrode design is extremely crucial for plasma jets.

2. Literature Review

The following studies show that different electrode configurations have a great influence on atmospheric pressure plasma jet. Optimizing the electrode design can not only reduce the plasma breakdown voltage and greatly reduce the cost, but also increase the plasma volume. As long as the ground electrode position is changed, the length of the plasma jet will increase with the increasing voltage[2]. Setting the microneedle array on the planar electrode can increase the volume of the plasma. As the number of microneedle array electrodes increases, the volume of the plasma also increases[3]. Changing different geometry shapes of high voltage electrode will affect the breakdown voltage, and will also change the active region, thereby changing the volume and uniformity of the plasma. Wang's group designed an inner coaxial electrode and found that a shorter inter axial needle distance combined with a longer needle length can generate the most uniform and high-density plasma[4].

Plasma is gaining increasing interest for cancer treatment because RONS can penetrate through the cell membrane[5]. Reactive oxygen species are key mediators of bactericidal effects of APPJ, which could be used as a potential alternative to antibiotic treatments *in vivo*[6]. APPJ can be applied directly on living tissues and, in this case, RONS reach directly the target, and it can for applying to dentistry[7]. Reactive oxygen and nitrogen species (RONS) are among the key factors in plasma medicine[8].

Therefore, the purpose of this study is to investigate the influence of different ground electrode positions and width, and the impact of different high voltage electrode with different geometry shapes, finding out the most efficient combination.

3. Motivation and Objective

Although previous researches have proposed the influence of different electrode configurations in APPJ, there is no research discuss the geometric shapes of high voltage electrode, the width and position of the ground electrode, and the impact on RONS production simultaneously. My objective is designing a APPJ device with high-productivity of RONS by changing electrode arrangement.

4. Methods

A schematic diagram of the experimental process for this study is shown in **Figure 1**, and a schematic diagram of the experimental setup for this study is shown in **Figure 2**. The working body of this study is argon gas, and the flow rate is controlled by a rotameter to 10 SLM throughout the process, and a power supply is used to provide a voltage of 4 kV and a sine wave with a working frequency of 20 kHz. Then connect the high voltage probe and the oscilloscope to monitor the parameters of the input plasma equipment.

The APPJ device is shown in **Figure 3** and **Figure 4**. The high voltage electrode is shown in **Figure 5**.

We designed different geometry shapes of high voltage electrodes, and the specifications are shown in **Table 1** and **Table 2**.

5. Experimental Results

The OES intensity of different high voltage electrodes is shown in **Figure 6**. We can roughly conclude that when the number of grooves increases, the intensity decreases accordingly.

The power consumption got by Lissajous figures are shown in **Table 3** and **Table 4**. The breakdown voltage got by Lissajous figures are shown in **Table 5** and **Table 6**.

Unlike the intensity of OES, there are no trends for breakdown voltage and power consumption.

6. References

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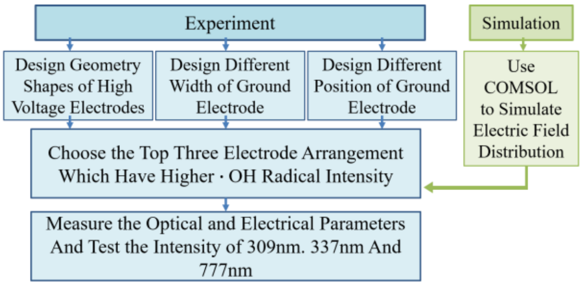

Fig. 1. Experimental process

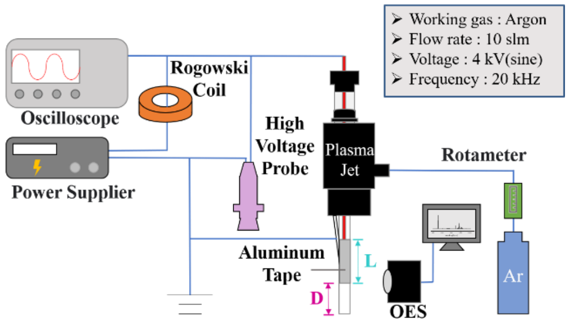

Fig. 2. Experimental setup

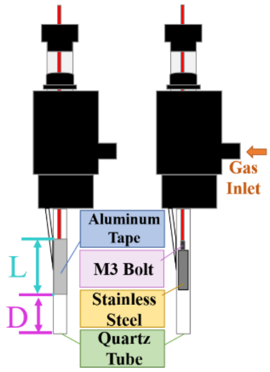

Fig. 3. Side view of APPJ device

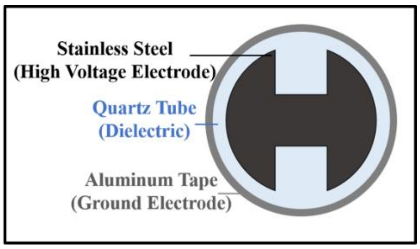

Fig. 4. Bottom view of APPJ device

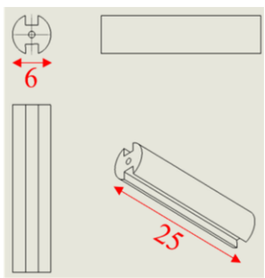

Fig. 5. Three view of two grooves electrode

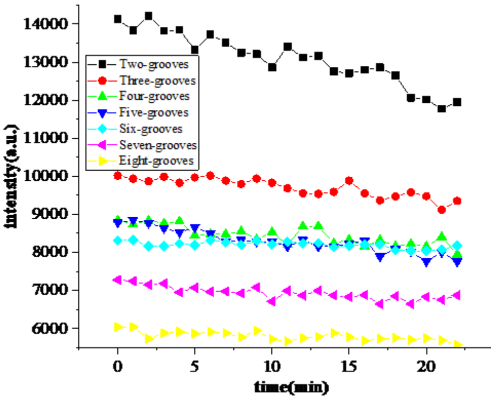

Fig. 6. The OES intensity of different electrodes

Table 1. High voltage electrodes (2~5 grooves)

High Voltage Electrode	Two Grooves	Three Grooves	Four Grooves	Five Grooves
Cross Sectional Area	21.43 mm^2	21.40 mm^2	21.37 mm^2	21.24 mm^2
Sectional View				

Table 2. High voltage electrodes (6~8 grooves)

High Voltage Electrode	Six Grooves	Seven Grooves	Eight Grooves
Cross Sectional Area	21.32 mm^2	21.34 mm^2	21.10 mm^2
Sectional View			

Table 3. Power consumption (2~5 grooves)

High Voltage Electrode	Two Grooves	Three Grooves	Four Grooves	Five Grooves
Power Consumption (W)	49.9673	43.5836	52.4374	54.3310

Table 4. Power consumption (6~8 grooves)

High Voltage Electrode	Six Grooves	Seven Grooves	Eight Grooves
Power Consumption (W)	53.6750	52.0551	54.2955

Table 3. Breakdown voltage (2~5 grooves)

High Voltage Electrode	Two Grooves	Three Grooves	Four Grooves	Five Grooves
Breakdown Voltage (V)	733.183	516.666	650	666.666

Table 3. Breakdown voltage (6~8 grooves)

High Voltage Electrode	Six Grooves	Seven Grooves	Eight Grooves
Breakdown Voltage (V)	683.334	666.516	666.516