EFFECT OF GROUND ELECTRODE ON STABILITY OF PLASMA JET

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ABSTRACT

An experimental study is presented of a cold atmospheric plasma jet with high plasma stability. To improve the performance of the plasma jet effectively, a coaxial-type electrode and a ground electrode of the variable position are applied. The discharge characteristics and stage evolution in different positions of ground electrode are measured, and the relationship between the position of ground electrode and the initial voltage of plasma jet is shown as a parabolic curve. The lowest point of the curve and the front end of the high voltage electrode are in the same plane, and the maximum range of the stable stage is also located in this position.

1 INTRODUCTION

Recently, atmospheric pressure plasma jets (APPJ) have been attracted wide attentions in science and engineering field. A plasma jet can be exited at a determined applied voltage, and be evolved with the increment of applied voltages. Lu et al.[1] demonstrate the influence of the discharge parameters to the length of plasma jet. Floating electrodes are introduced to improve the performances of plasma jets, Wang et al.[2-3] describe that the floating electrode is beneficial to control the development of discharge intensity and restrict the transition from glow-like discharge to arc. The evolution of plasma jet can be divided into the initial, stable, and unstable stages with the increase of the applied voltage. Nie et al. [4-6] define them and describe the phenomenon. In this paper, by changing the position of the ground electrode, through the measurement of initial voltage and characteristics of the discharge voltage and current in stable and unstable stages, we will report the effect of ground electrode to the stages of plasma jet.

2 EXPERIMENT SETUP

The schematic of the experimental device is shown in Fig.(1). A coaxial-type plasma generator is applied, which consists of a inner rod electrode, a dielectric glass tube, and a grounded outer ring electrode. The high voltage electrode is made of a screw like stainless steel metallic rod with uniform threads on the surface, the glass tube with the inner diameter and thickness of 7mm and 0.5mm, the outer ring electrode is a circular metal structure and the diameter is 7.1mm, it can move smoothly along the axis of the glass tube, the plasma generator is driven by a high-voltage alternating current power supply at a frequency of 45kHz. The argon is used as carrier gas (with a purity of 99.999%), it flow rate is fixed at 6slm by using a mass flow controller. The applied voltage is measured by using the high-voltage probe. Through the resistor, the discharge current is converted into the voltage signal, and recorded via a Tektronix DOP2024 oscilloscope (200MHz bandwidth and 10 mega-bit sample record length) . For optical diagnostics, the discharge images are captured by a digital camera (SONY NEX-F3).

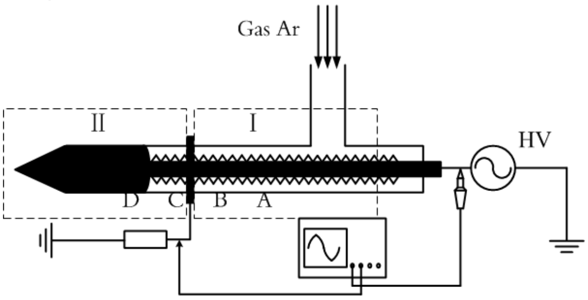

Fig.1 Schematic of the experimental device

3 EXPERIMENT RESULT AND DISCUSSION

3.1 Electrical Characteristics and Typical Discharge Images

As shown in Fig.(2), the plasma jet process can be divided into three stages: initial, stable and unstable stages, Fig.(3) shows the waveforms of the applied voltage and current in stable and unstable stages. With the increase of the applied voltage, it can be seen that, when it is raised over the breakdown threshold, a bright discharge ring is observed between the inner and ground electrodes. As the applied voltage is increased, the argon discharge occupies the whole space of the electrode region, and plasma with good uniformity and stability can be obtained. The discharge current is of a sinusoidal profile with some fairly weak micropeaks, the discharge turns into the stable stage. With the further increase of the applied voltage, the plasma jet becomes unstable, near the geometrical axis of the glass tube, the concentrated bright discharge can be observed, the micropeaks on the current waveform become more obvious as shown in Fig.3(b).

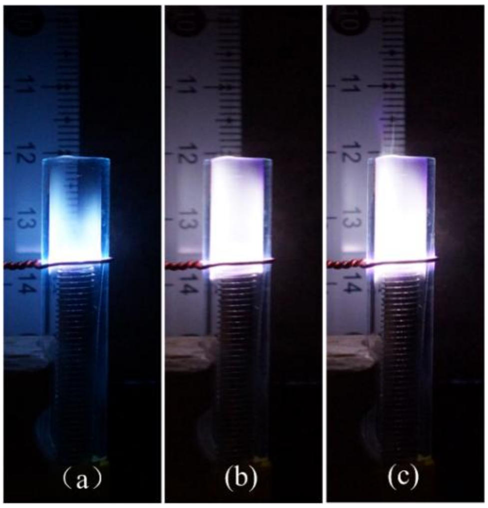

Fig.2 Evolution of the atmospheric pressure plasma jet with a ground electrode in position C (a) initial stage; (b) stable stage; (c) unstable stage

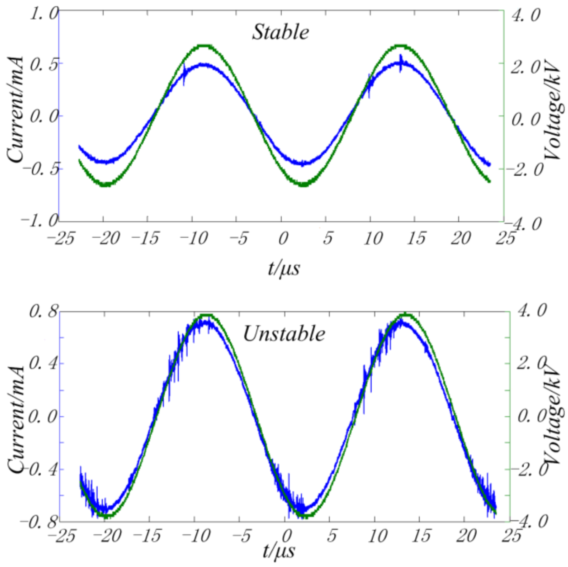

Fig.3 Characteristic wave forms of the discharge voltage and current corresponding to the stable stage and the unstable stage in Fig.2(b) and 2(c)

3.2 Result and Discussion

The ground electrode can be located in four positions, the distance between the front end of inner electrode and position B, position D is 5mm; position A and position C are symmetrical about position B, the distance is also 5mm. Change the position of ground electrode, when it is in position B, the initial driving voltage U_1=2.36kV. The plasma jet can be changed into the stable stage with the increase of the driving voltage. When the voltage exceeds U_2=3.88kV, the plasma jets become into the instable stage. When the ground electrode is in position C, the initial discharge voltage is U_3=2.12kV. When the voltage exceeds U_4=3.96kV, the plasma jets become into the unstable stage. When it is in position D, the initial driving voltage is U_5=3.40kV, the plasma jet becomes into the unstable stage until the voltage exceeds U_6=4.04kV.

As can be seen in Fig.4, the minimum initial voltage is present at position C, and when the ground electrode in position D, the initial voltage is the maximum. Besides, it has the narrowest range of voltages in position A. As the ground electrode is in position D, the area of the interface between the ground electrode and the inner electrode, more residual charges are trapped on the tube surface, and more seed electrons need to be supply. Besides, the low electric field intensity, which may be lead by the gap distance between high voltage and ground electrodes are also unfavorable to discharge, so the initial voltage is higher. For the case of ground electrode in position A , position B and position C. In the propagation of plasma jet, there might be two kinds of electric fields, one is existed between the high voltage and the ground electrode, and the self-induced electric field is the other. The high voltage electrode and ground ring could be seen as the DBD discharge, the inner electrode in area II is worked as the floating electrode, the longer of the length of electrode, the more charge tend to be gathered. Therefore, when the ground electrode is located in position A, it would be need a higher input voltage to generate DBD, however, the input voltage which is varied in a small range may lead to different stages of plasma jet.

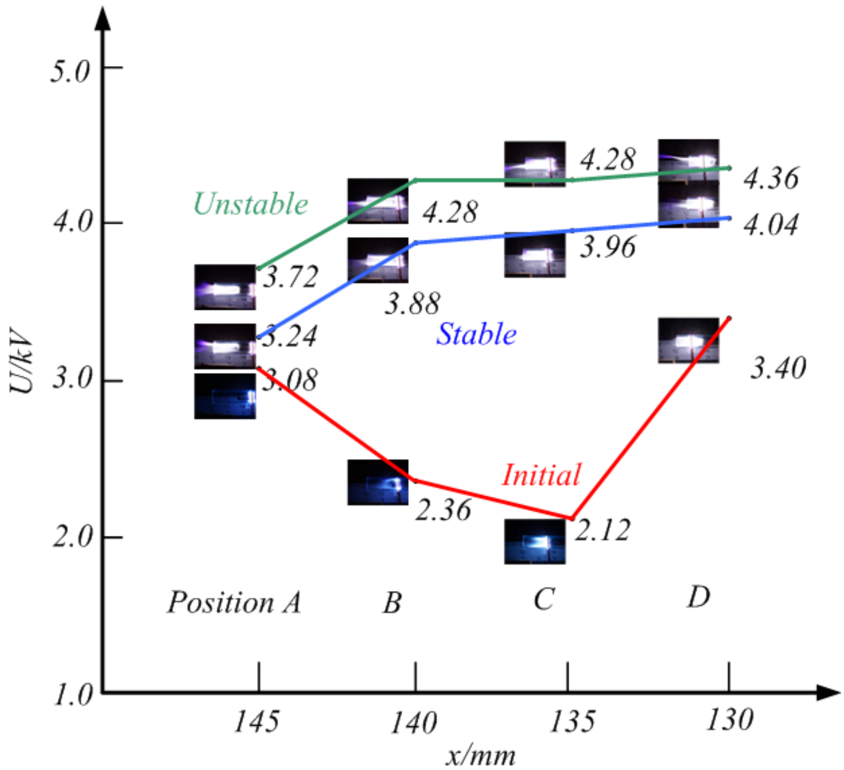

Fig.4 Plasma jet for different position of grounding electrode

4 CONCLUTION

In this paper, a coaxial-type plasma generator is adopted. The main conclusions are as follows.

(1) Relationship between the position of ground electrode and the initial voltage of plasma jet is shown as the parabolic. The lowest point of the curve and the front end of the high voltage electrode are in the same plane.

(2) Maximum range of the stable stage exists at the position which has the minimum initial voltage.

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