IOSR Journal of Research & Method in Education (IOSR-JRME)
e-ISSN: 2320–7388,p-ISSN: 2320–737X Volume 4, Issue 3 Ver. II (May-Jun. 2014), PP 81-84
www.iosrjournals.org

Effects of the small diameter and the flow rate on the electric properties of the plasma needle

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Abstract: *A syringe needle assembled with a glass tube has been used as a plasma jet device for biomedical applications. According to the various electrode diameter of power electrode installed inside the glass tube, helium plasma from an atmospheric pressure discharge has been investigated. The discharge is driven by pulsed direct current voltages.*

It is found that the measured discharge current was remain very low with increasing applied voltage from zero up to given applied voltage (breakdown voltage), the value of breakdown voltage depends on the value of electrode diameter and flow rate of the helium, The discharge current was increased suddenly at breakdown voltage reached maximum value and remain nearly stable with applied voltage. The discharge current increases with applied voltage and flow helium rate but decreases with electrode diameter.

Key words: *Cold Atmospheric Plasma, plasma needle, power supply, beams of plasma.*

I. Introduction

Cold Atmospheric Plasma (CAP) is known as non-thermal because it has electrons at a hotter temperature than the heavy particles that are at room temperature. Its temperature is less than 104°F at the point of application. Cold atmospheric plasma have range of applications in industrial and scientific such as biomedical applications,[1,2] biological sterilization, [3,4] nanoscience,[5] and material processing.[6,7] .Various methods to produce cold atmospheric plasma include Dielectric Barrier Discharge (DBD), Atmospheric Pressure Plasma Jet (APPJ), plasma needle, and plasma pencil. Gases that can be used to produce CAP are Helium, Argon, Nitrogen, or mixed of helium and oxygen, and air [8]. Several plasma jets with pulsed dc power have been developed [9–12] with voltages in the kilovolts range and pulse widths in the range from a nanosecond to a microsecond at kilohertz repetition rates. The plasma jets driven by ac power are usually generated by a dielectric barrier discharge with a few kilovolts sinusoidal wave at frequencies in the range of 5–50 kHz [13–16]. Recently, plasma jets have been also reported by an ac discharge [17]. In recent years, a relatively large number of radio frequency (RF)-driven jets have been developed [18–23]. Because of its mild plasma and geometry, plasma needle is especially convenient for medical applications. Non contact disinfection of dental cavities and wounds and minimum destructive precise treatment and removal of diseased tissue can be done by a plasma needle [24]. The treatment can be done with less than 0.1 mm accuracy. The goal is to separate the cells without causing the necrosis of the cells or in some situations to induce apoptosis. Biological samples like plant tissue can also be easily treated [25]. For the purpose of successful treatment and comparison of different samples by plasma needle it is necessary to characterize the plasma itself the best way possible. The standard parameters for treatment of samples are duration of treatment, power transmitted to the plasma and distance of the sample to the tip of the needle. For the power measurements the derivative probes were used. The percentage of the total power distributed to plasma itself was determined from the recorded voltage and current waveforms [26].

Our study deals with Effects of small diameter and flow rate on the electric properties of the plasma needle.

II. Experiment and methodology

The experimental arrangement is shown in Fig. 1. It consists of four main Parts: high voltage power supply plasma needle, helium gas, flow-rate control. The homemade high voltage power supply was made based on flyback transformer, it is able to generate high voltage between (0 - 10 kV) and frequencies (0 - 40 kHz).

The plasma needle is made of glass tube and another stainless steel tube concentrated inside the glass tube they are used for guiding the gas flow. The stainless steel tube also serves as high voltage e electrode (the anode), which is connected to a high-voltage (HV), the stainless steel tube is made of different outer diameters (2.7, 3.5, 5.1, 6) mm and the glass tube is made of different inner diameters(1,4.4,5.3,10.6) mm as shown in Figs.1and 2, the stainless steel tube covered with a Teflon tape insulator except 5 mm was left without Teflon tape insulator. The distance from the tip of the stainless steel tube to the nozzle of the glass tube was about (10 mm). The helium gas was used as working gas to generate plasma, The helium gas was controlled by flow rate

regulator (model MFG.CO.LTD. Tube, England). The gas flow can be adjusted in the range of (0–5) l/min. A voltage probe P6150A by Tektronix was attached to the feed-through of the needle when voltage measurements were carried out. The probe was a 1000×attenuator with 100M resistance and 3 pF capacitance.
The plasma temperature was measured with digital thermocouple (DFP 450 W, Waterproof). To prevent the thermocouple to become an extra-electrode of the discharge, it is covered by Teflon tape.

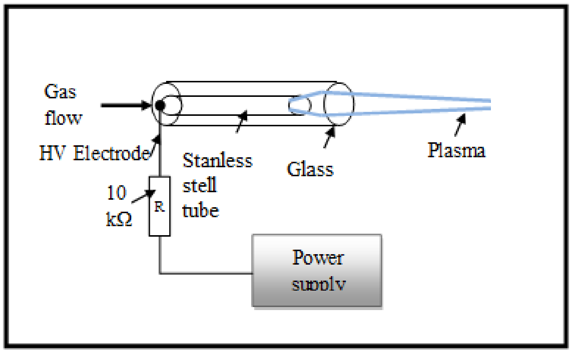

Figure .1. sketch the design for plasma needle .

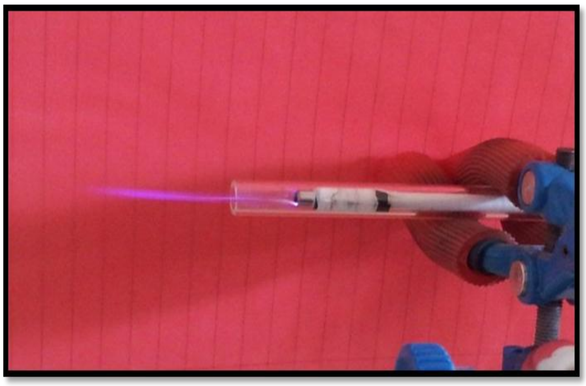

Figure. 2. plasma plume.

III. Results and discussion

Fig. 3 (a, b, c, d) shows the discharge current as a function of applied voltage for three different values of the rate of flow of helium gas which is (2, 3, 4) l /min. and four different diameters of the electrode diameter (2.7, 3.5, 5.0, 6.0) mm.

It is found that with increasing applied voltage from (0 to about 600 V), the values of discharge current record a few microcurrent caused by displacement current, however, when the plasma plume start appear, the discharge current increase sharply up to point depends on the flow rate and electrode diameter.

It is observed that the length of the plasma plume increase with increasing applied voltage and reach maximum length of about 1kV, also the discharge current get maximum value and stay at this value with increasing applied voltage.

Also, it is found that for fixed applied voltage the discharge current increase with increasing helium flow rate as shown in Fig. 4

Fig. 5 shows the discharge current as a function of the electrode diameter for three different value of the flow rate (2,3,4) l/min. and fixed applied voltage (2 kV). It can be shown that for small electrode diameter (less than 5 mm) the discharge current decrease with electrode diameter, but with increasing electrode diameter (greater than 5 mm) the effect of the diameter becomes not be significant.

IV. Conclusion

A plasma jet device has been introduced in this paper for biomedical applications. The plasma jet system assembled with a syringe and a glass tube has been investigated according to various types of powered electrode installed inside glass tube. The discharge is driven by pulsed direct current voltages power supply is used. The output DC voltage in the power supply is variable in the range of 0–5 kV by adjustment of the input ac voltage in the range of 0–50 V. The operating frequency is in the range (100-1500) Hz. In the case of no ground electrode and a floating electrode, the length of the plasma plume is about 10 mm at an ignition voltage as high as 1 kV, and it extended to 50 mm as the applied voltage was increased to 3 kV. When the cupper ring used as ground electrode was installed at the end the glass tube or a floating electrode was used the operating voltage was reduced as low as 0.5 kV at ignition. After ignition, the length of the plasma plume exiting out of the glass was about 1 mm, and it was adjustable up to 10 mm, increasing linearly with voltage. The value of the needle diameter, quantity of the helium flow rate as well as the plasma current with the operation voltage was easily adjustable with the operating voltage, with the external ground electrode located on the glass tube surface. These experimental results have provided information which will be useful in the decisions to be made about the commercialization of the plasma jet device for biomedical applications.

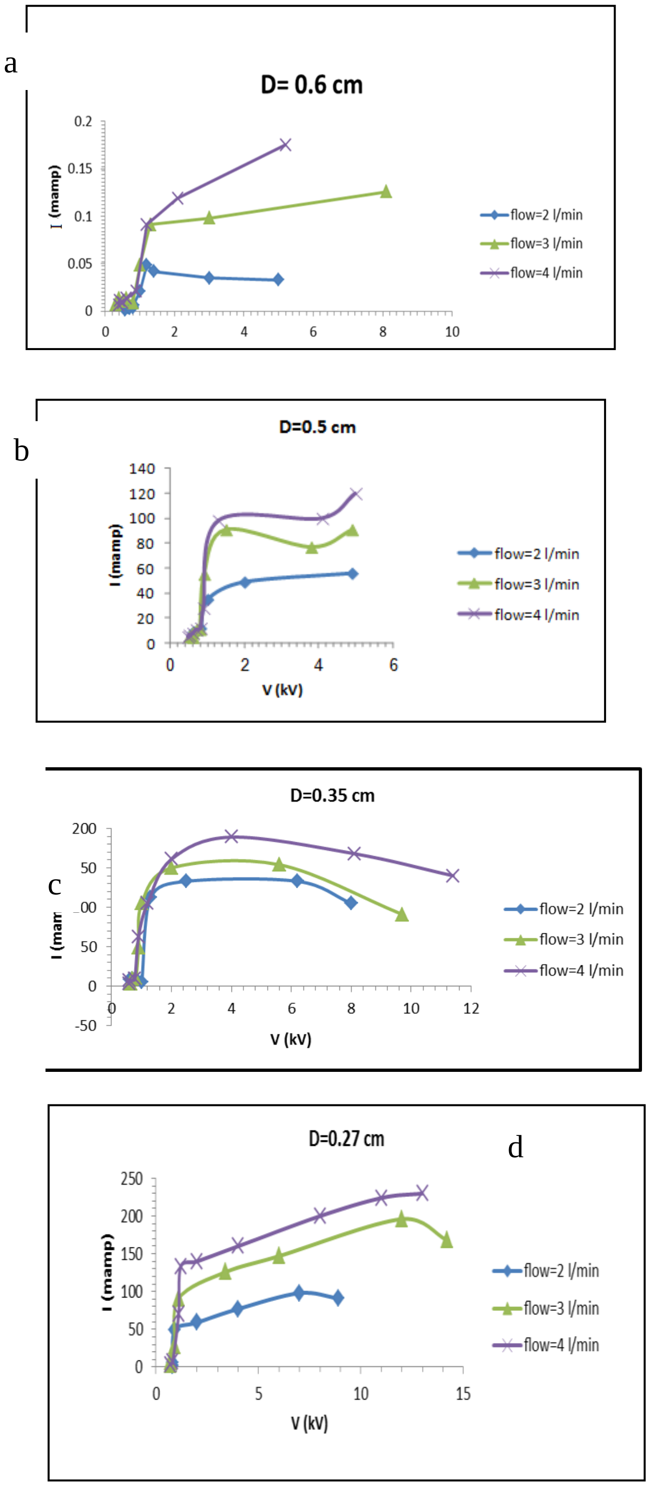

Fig. 3 (a, b, c, d) The discharge current as a function of applied voltage for three different values of the helium gas flow rate (2, 3, 4) l /min. and four different values of the electrode diameter (2.7, 3.5, 5.0, 6.0) mm.

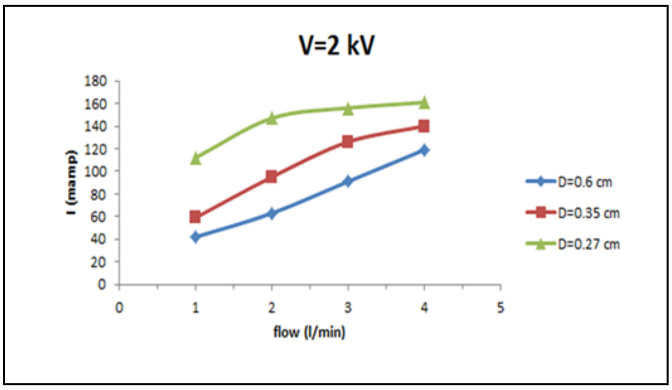

Fig. 4. The discharge current as a function of helium flow rate for three different values of the electrode diameter (2.7, 3.5, 6.0) mm and fixed applied voltage V=2 kV.

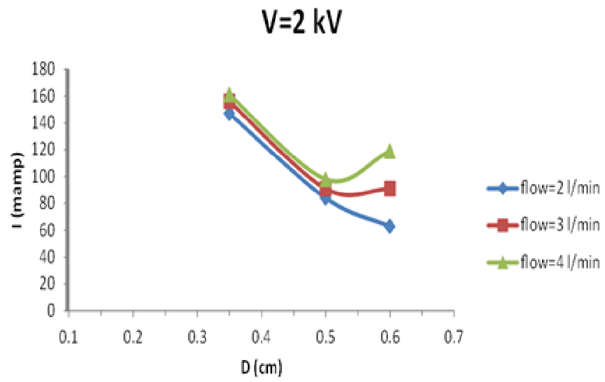

Fig.5 The discharge current as a function of the electrode diameter for three different value of the flow rate (2, 3, 4) l/min. and fixed applied voltage (2 kV)

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