DOI: 10.24996/ ijs.2017.58.3B.9

Iraqi Journal of Science
ISSN: 0067-2904

The Study of Electrical Description for Non-Thermal Plasma Needle System

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Abstract

In this research, a non-thermal plasma system was designed and a non-thermal plasma needle was manufactured for argon gas operating at normal atmospheric pressure. The electrical description of this system studied by using two different values of voltages (4.9,8) kV. Where the results showed the small amount of electrical current consumed by the system of plasma needle up to several microns of amps, and the value of the electrical current increase with the increasing gas flow, as well as the results, showed that happen a breakdown voltage at (8) kV when gas flow (4 l/min) causing a slight decrease in the electrical current value.

Keywords: Non thermal plasma ,plasma needle, Electrical description.

دراسة التوصيف الكهربائي لمنظومة ابرة البلازما غير الحرارية

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الخلاصة

في هذا البحث، تم تصميم وتصنيع منظومة بلازما غير الحرارية لغاز الأرجون والتي تعمل عند الضغط الجوي الاعتيادي. حيث تم دراسة الوصف الكهربائي لهذه المنظومة المصنعة وذلك من خلال استخدام قيمتين مختلفتين من الفولتية (4.9,8) كيلو فولت.

حيث اظهرت النتائج التي تم الحصول عليها صغر قيمة التيار الكهربائي المستهلك من قبل منظومة أبرة البلازما غير الحرارية حيث كان بحدود عدة مايكرونات من الامبير ، وكانت قيمة التيار الكهربائي تزداد زيادة طردية مع زيادة تدفق الغاز ، وكذلك اظهرت النتائج حدوث انهيار في الفولتية عندما تكون الفولتية المستخدمة (8) كيلو فولت والتي سببت انخفاض قليل في قيمة التيار الكهربائي عندما يكون تدفق الغاز (4 لتر/دقيقة).

Introduction

The plasma It described as ionized gas and fourth state of matter containing free charge carriers (electrons and ions), since the plasma constitute 99% of the Universe such as solar corona, solar wind, nebula, earth´s ionosphere and therefore, many physical processes require the understanding of terrestrial and extraterrestrial plasmas [1]. Because of the large temperature and density ranges of the

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plasma, so there are several applications in many fields of research, including in technology, industry and medicine, the plasma used in the industry widely throughout the world for a broad variety of industrial applications covering industries such as extractive minerals, automotive, aerospace, batteries, electrical, food packaging, electronics, fuel cells, glass, optics, plastics, packaging, shipbuilding, space [2].

Accelerated electrons provide the basis for further excitation, dissociation and reaction processes upon collision with other bodies that leads to the multicomponent nature of plasma: electrons, ions, excited molecules, neutrals like radicals and light. Further properties of plasma include a gas temperature range from room to solar temperature, electron densities from (10^6 - 10^{18}) cm^{-3} and electron temperatures from (1 eV - 20 keV) (1 eV ≈ 11600 K) [3].

Non-thermal plasma (NTP) is a weakly ionized gas far from thermodynamic equilibrium. While electron temperature is 1-10 eV, electrons are not able to transfer their entire kinetic energy gained from an externally applied electric field onto bigger particles and thus the gas remains non-thermal ($T_e >> T_g$; $T_g \approx 300 - 1000$ K [4]). Non-thermal plasma is characterized by the different energy states between electrons, ions and neutral molecules [5]. Because the ions and the neutrals remain relatively cold, this characteristic provides the possibility of using cold plasmas for the treatment of heat sensitive materials including polymers and biological tissues [6]. Plasma needle is a type of non-thermal glow discharge which operates under normal atmospheric pressure and is composed of one pole or two poles, one called the cathode and the other is named the anode and run on the noble gases. one of the important characteristics of this type of plasma approach it to room temperature and operating under normal atmospheric pressure as it allows for processing of sensitive surfaces, as well as can penetrate the small depths [7]. The remarkable characteristic features of cold plasma that include a strong thermodynamic non equilibrium nature, low gas temperature, presence of reactive chemical species and high selectivity offer a tremendous potential to utilize these cold plasma sources in a wide range of applications [8].

Electrical Characterization

The measurement of voltages and current provides the possibility to describe the characteristics of plasma and mainly plasma power. The plasma power (P) given by the following equation [9]:

$$P = \frac{1}{T}\int_0^T u(t).I(t)dt$$

where u the voltage, I the current and T is the oscillation period.

High voltages probe to measure out voltages, as well as the case for the outside current as measured by the current probe [10]. In terms of the out plasma velocity because of a collapse in the ionization they will grow and multiply at each period of the current and voltages, initially will be increased gradually as up to about (2×10^4 m/s) then begin to slow as up to half the speed mentioned after 0.3μs and in the air start upward to reach the original speed in the range of 0.7μs [11].

Experiment Setup

Figure-1 shows design non-thermal plasma needle where the device is a tube on cylindrical shape, inner diameter of (5) mm and a length of (12) cm made of PYREX glass thickness (1) mm, open on both sides and has a slot width (3) mm from (4) cm to the top of the tube allows to the flow of argon gas.

The inner electrode from metal stainless its diameter is (3 mm) represents the cathode, The external electrode made from a copper represents anode thick (0.8 mm) placed outside the tube at the front of the needle and was isolated by silicon to prevent discharge at the tip of the needle. The non-thermal plasma needle system linked to power supply (AC) range voltages (0-30) kV, the inner electrode of the needle connected to the cathode source of power supply, whereas external electrode of the needle connected to the anode source of power supply.

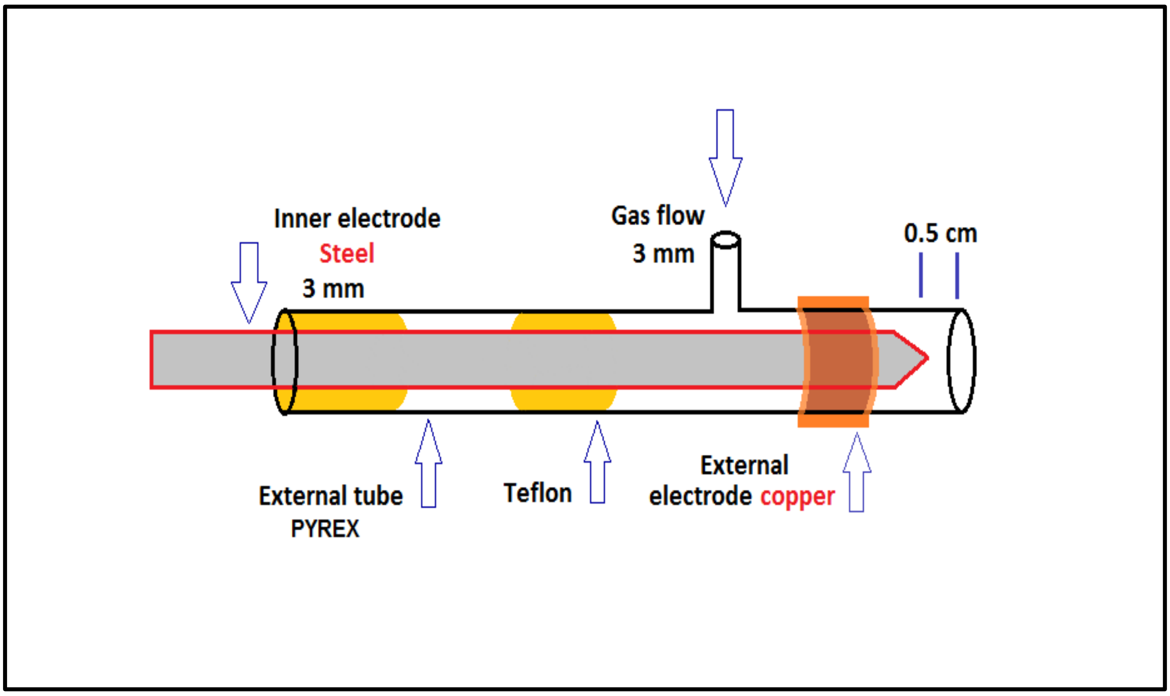

Figure-1 Schematic for design non thermal plasma needle.

All the instruments of the non-thermal plasma needle system were connected. The system of non-thermal plasma needle used argon gas, as gas flow rate instrument and metal holder to needle plasma. Figure-2 shows the non-thermal plasma needle system used in this study and its electrical properties were studied.

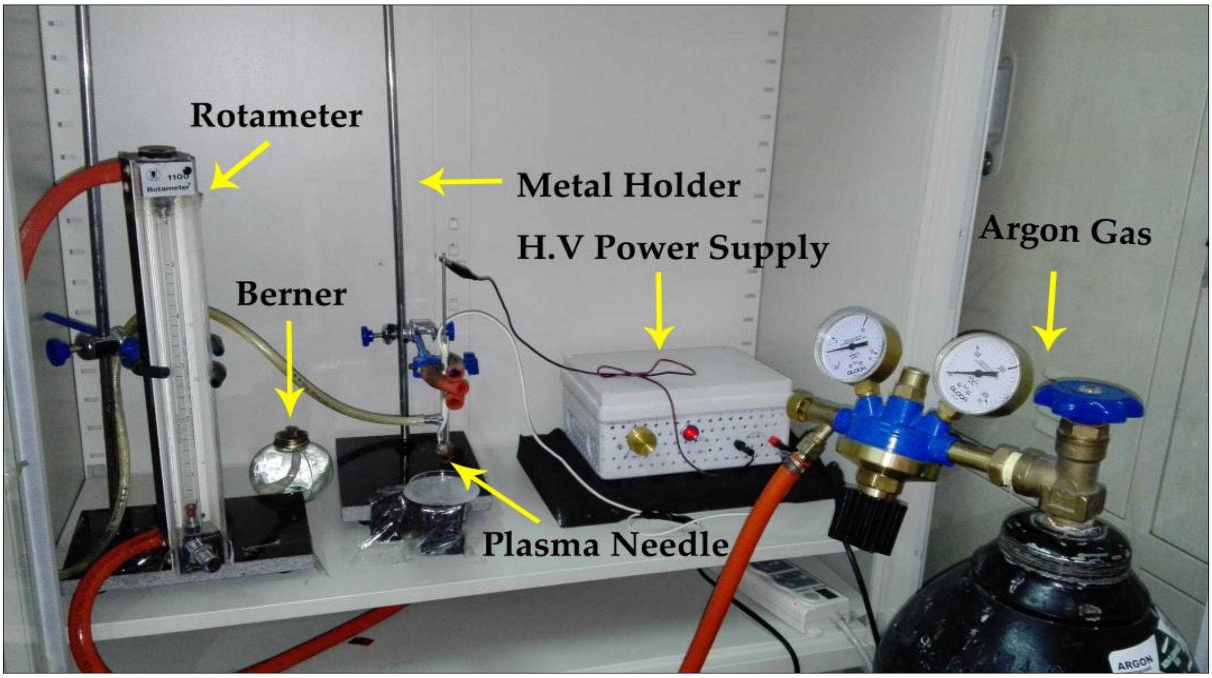

Figure 2-Image of Non-Thermal Plasma Needle System.

Method:

The voltages measured by using a probe type of high voltages (Probe Fluke) of the measurement range (0-40) kV and by transforming (1/1000). The electrical current was measured by segmentation of voltages by attaching a resistor with ($R = 8\Omega$) to the cathode path and measuring the voltages on

both ends of resistor by using a device (Digital Multimeter) and calculating the current passing through it. Figure-3 shows the electrical circuit of the non-thermal plasma needle system.
Where taken different values of voltages and by segmentation the voltages by resistance, extracted current values. Tow values of the voltages are depending (4.9 , 8) kV with change in gas flow values (1-5 *l/min*) to show the effect the change in gas flow on the values of electrical current at the voltage values after then measured the electric current used in this system.

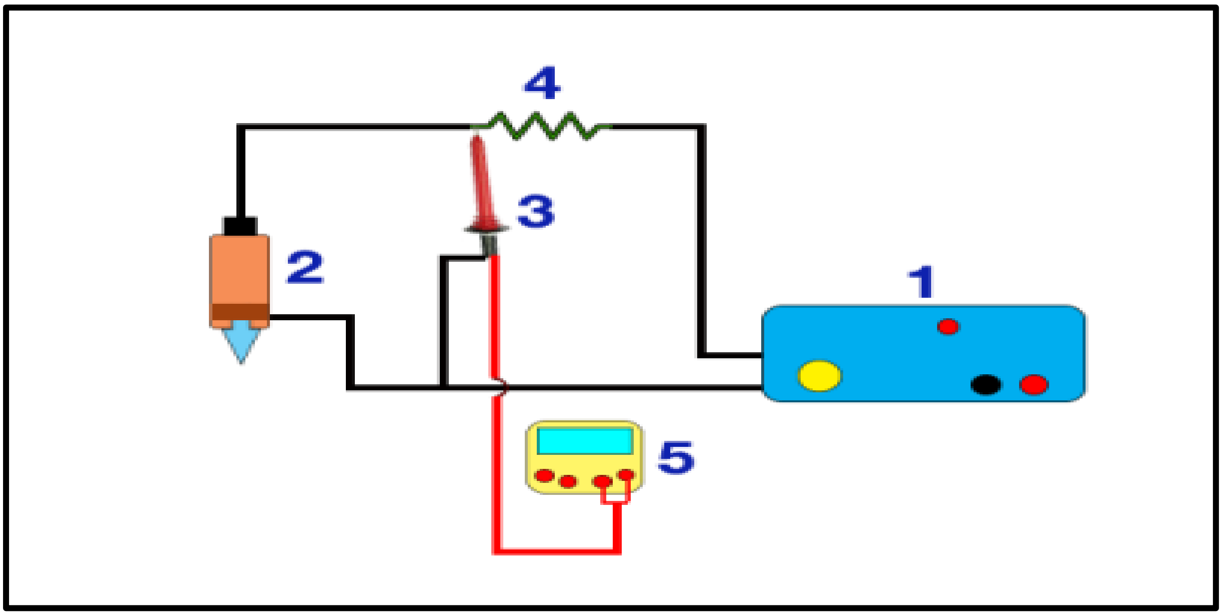

Figure 3-Schema illustrating connection of an electrical circuit of non-thermal plasma needle system, where: 1- HV power supply, 2- non-thermal plasma needle, 3- HV probe, 4- resistor 8 Ω,5- Digital multimeter.

Results and Discussion:
Study I-V Curve For non-thermal Plasma Needle System:

The results obtained show that the electrical current values are very small in this non-thermal plasma system when using different values of voltages. The relationship between the current as a function of the voltages and a different flow of argon gas (1,3,5 *l/min*). the general behavior of the current-voltages is not very different at all gas flow velocity and is somewhat similar, since the current values are very few microns and then recorded a slight increase with the increase of voltages up to reach a certain value and then happens the so-called breakdown voltages, this value depends on the velocity of the argon gas flow, and once the breakdown voltages occur, the plasma is produced by the needle, the intensity and size of the plasma generated varies with the velocity of the gas flow**.** The fig. (4) shows the relationship between the current as a function of the voltages and a different flow of argon gas (1,3,5 *l/min*).

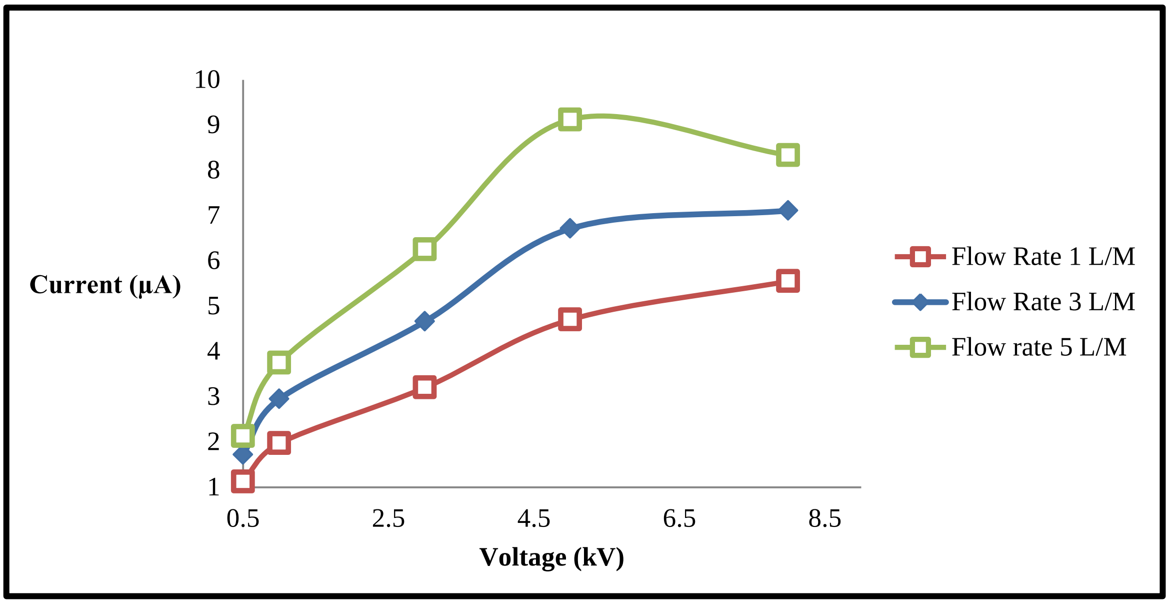

Figure 4-shows the relationship between the current as a function of the voltages and a different flow of argon gas (1, 3, 5 *l/ min*).

Where the general behavior of the current-voltages is not very different at all gas flow velocity and is somewhat similar, since the current values are very few microns and then recorded a slight increase with the increase of voltages up to reach a certain value and then happens the so-called breakdown voltages, this value depends on the velocity of the argon gas flow, and once the breakdown voltages occur, the plasma is produced by the needle, the intensity and size of the plasma generated varies with the velocity of the gas flow.

Also, it is found that the values of the current increase at the breakdown voltage to a certain value vary according to the velocity of gas flow, and current values continue on this case with a slight decrease when increasing the voltages.

This can be explained, when the voltages are small (less than the breakdown voltages), the energy processed to the molecules by the electric field is low and is incapable of producing elementary and secondary ionization to molecules, and by increasing voltages, begins the initial ionization of the molecules and register low values for the current.

When reached to the breakdown voltage, the energy supplied to the molecules by the electric field is sufficient to cause the secondary ionization of the molecules, during this most of the passing gas molecules are ionize through the plasma needle, and the passing gas converts to the plasma state. The Figure -5shows the relationship between the current as a function of the flow of gas at a voltage of (4.9) kV. At the first voltages, when the flow of gas is increased, the current is increased significantly, this increase in current value is due to the increase in the number of gas molecules passing through the electrode, and thus lead to frequent collisions between molecules and then happen ionization of molecules, which leads to higher value of current when increasing the flow of gas.

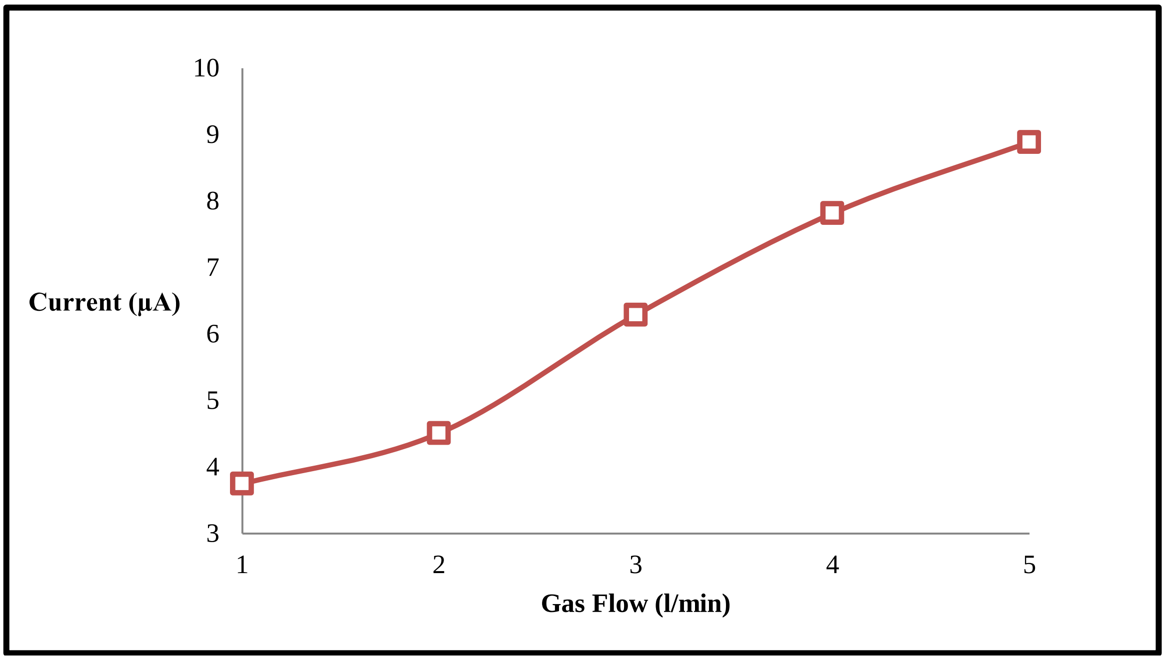

Figure 5-shows the relationship between the current as a function of the flow of gas at a voltage of (4.9)kV.

At the second voltage are increased to (8) kV and the gas flow is increased, the current value is increased when the gas flow values are increased to reach the breakdown voltage for the gas, causing a slight decrease in the current value, this slight decrease in the current value occurs at the higher gas flow (5 *l/min*), which explains the large collision between the gas molecules, which causes plasma generating in the tube, whose intensity varies according to the flow velocity of the argon gas. The Figure-6 shows the relationship between the current as a function of the flow of gas at a voltage of (8 kV).

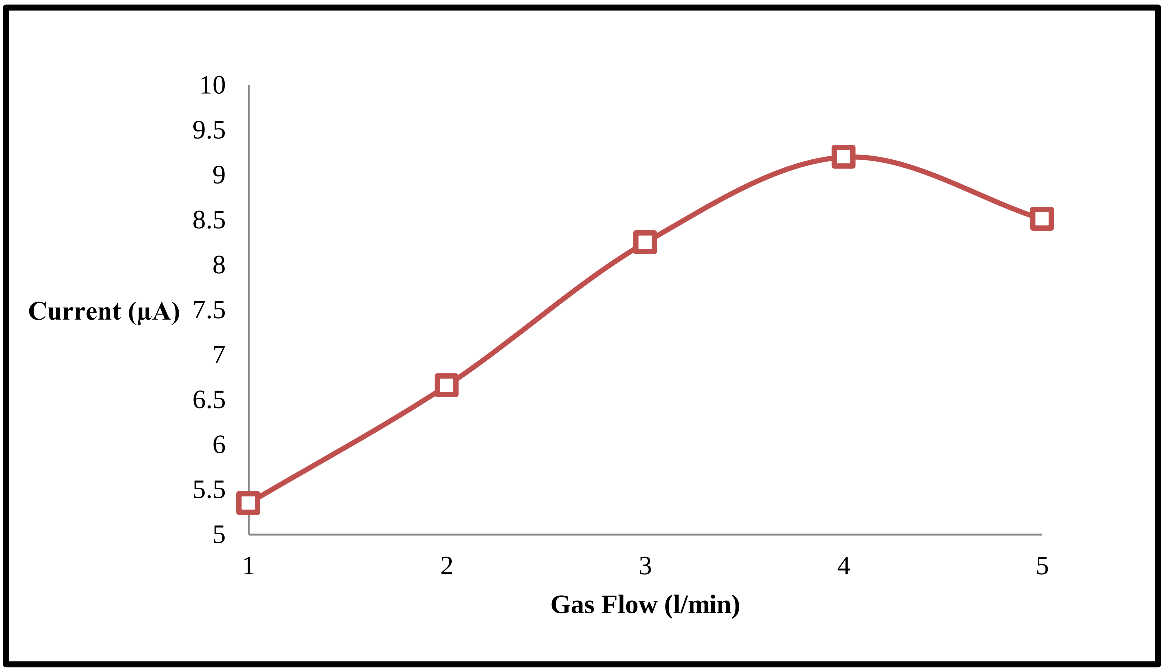

Figure 6-shows the relationship between the current as a function of the flow of gas at a voltage of (8)kV.

After the silent discharge voltage, the discharge current increases rapidly with the increase of the applied voltage. Because the electrons gain energy to cause further ionization causing an electron avalanche and leading then to the formation of discharge inside of the plasma needle system [12].

Conclusions

From the above results, one can conclude that:

1. The current values are very few microns which makes the non-thermal plasma needle system suitable for medical and biological use without causing any damage.
2. The electrical current increases with the increased Applied voltages as this increase depends on the gas flow velocity.
3. The highest electrical current value is (9.1 µA) occurs when the voltage used (8 kV), while the electrical current is less than (9 µA) when the voltages used are (4.9 kV).

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