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The study of thermal description for non-thermal plasma needle system

Ahmed Mahmoud Shihab[1], Mohammed Ubaid Hussein[2], Hamid H. Murbat[3], Salam Dawood Muhamed[1]

[1]Department of Physics, College of Science, Anbar University

[2]Department of Physiology and Medical Physics, College of Medicine, Anbar University

[3]Department of Physics, College of Science women, University of Baghdad

E-mail: ahmedmsh049@gmail.com

Abstract

Cold plasma is a relatively low temperature gas, so this feature enables us to use cold plasma to treat thermally sensitive materials including polymers and biologic tissues. In this research, the non-thermal plasma system is designed with diameter (3 mm, 10 mm) Argon at atmospheric pressure as well as to be suitable for use in medical and biotechnological applications.

The thermal description of this system was studied and we observed the effect of the diameter of the plasma needle on the plasma, when the plasma needle slot is increased the plasma temperature decrease, as well as the effect of the voltages applied to the temperature of the plasma, where the temperature increasing with increasing the applied voltage . Results showed that the plasma temperature would be low, which enables the use of this system in many medical aspects.

Key words

Non-thermal plasma, plasma needle, thermal description.

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دراسة الوصف الحراري لمنظومة إبرة البلازما غير الحرارية

احمد محمود شهاب[1]، محمد عبيد حسين[2]، حامد حافظ مربط[3]، سلام داود محمد[1]

[1]قسم الفيزياء، كلية العلوم، جامعة الانبار

[2]قسم الفسلجة والفيزياء الطبية، كلية الطب، جامعة الانبار

[3]قسم الفيزياء، كلية العلوم للبنات، جامعة بغداد، بغداد-العراق

الخلاصة

البلازما الباردة هي غاز درجة حرارته منخفضة نسبيا، لذلك هذه الميزة تمكننا من استخدام البلازما الباردة لعلاج المواد الحساسة حراريا بما في ذلك البوليمرات والأنسجة البيولوجية. في هذا البحث تم تصميم منظومة بلازما الأرجون غير الحراري بقطر (3 و 10) مم عند الضغط الجوي، وكذلك لتكون مناسبة للاستخدام في التطبيقات الطبية والبيوتكنولوجية. تم دراسة الوصف الحراري لهذه المنظومة ولاحظنا تأثير قطر ابرة البلازما على درجة حرارة البلازما فانه كلما زاد نصف قطر الابرة فان درجة حرارة البلازما تقل، وكذلك تأثير الفولتية المطبقة على درجة حرارة البلازما حيث تزداد كلما زادت مقدار الفولتية، وأظهرت النتائج أن درجة حرارة البلازما ستكون منخفضة، والتي تمكن من استخدام هذا النظام في العديد من الجوانب الطبية.

Introduction

The certain thought that the cosmology consist of four main components: the earth, water, air, and fire. On the earth occur the air and water assimilated the liquids and gases in the visible universe, and the plasma is the fourth state and exactly fire [1].

Plasma is ionized gas, also can be defined as a quasi-neutral gas of charged particles (electrons and ions), though a moving molecules produce position assemblage of positive charge or negative charge that produce electric field with the moving of charged molecules and neutral, generate magnetic field. This fields is react by moving molecules [2].

Over 99% of the visible universe is consist of plasma. For example the matter a sun and stars or nebulae is plasma. Many applications have been investigated and developed using plasma discharges based on different geometric appearance using different gases, various material for the electrodes in a large sustain the discharges using various power sources and sometime additional features like magnetic field or heating [3].

The recent trends focused on the use of plasma to sterilize medical equipment and treatment of living tissue as the main goal of treatment of plasma tissue surgery is not to cause any damage. The degree of electron temperature is usually the largest 10^4 $K°$, while the temperature of each of the neutral particles and ions are highly dependent on the type of plasma-producing it can vary almost temperature from room temperature to 10^7 K°. A well-known example of plasma in nature is the sun. Is usually for each class of plasma components of the degree of his own any degree heat of electrons T_e , positive ions T_i and neutral particles T_n. So can say that plasma is the only substance that contains several degrees of heat at the same time [4, 5].

In this type of plasma ions and neutral particles temperature surrounding itself, the degree of electron temperature rises much bigger that any other particles (T_e>>T_i≈T_n). In cold plasma, most processed energy into electrons in the plasma, and this produces an effective electrons instead of heating gas as a whole, because of ions and neutral components remain relatively cool, this feature will enable us to use cold plasma processing thermally sensitive materials, including the polymers and biological tissue [6].

Thermal properties

Unbalanced plasma is often called "non-thermal" plasma. In this type of plasma the electron temperature is 100 to 1000 times higher than the neutral gas temperature.

In this way, the light particles (electrons) are chemically active, while the temperature of the gas atoms is fixed at room temperature or higher to avoid thermal damage. There are many techniques used to measure the temperature of the plasma, including the use of thermal probe [1].

Where any atom or molecule can be converted to a positive ion with negative electrons, and the ionization ratio depends on the kinetic energy of the gas molecules, in other words, it depends on the temperature of the gas, as in the Saha equation to calculate the score of the ion [7].

$$\frac{n_i}{n_n} = 2.4 \times 10^{12} \frac{T^{\frac{3}{2}}}{n_i} \text{ EXP - } \left(\frac{u_i}{K_B T}\right) \qquad (1)$$

where:

$\frac{n_i}{n_n}$: Ionization ratio

n_i: Numerical density of charged particles of volume unit (m^3).

n_n: The numerical density of the neutral particles of gas (m^{-3}).

u_i: Energy gas ionization (Jul).

K_B: Boltzmann constant (J / K).

T: Gas temperature (K)

Experimental setup

Two types of non-thermal plasma needle are designed where the device is cylindrical-shaped tube, inner diameter of 3 and 10 mm and length 14 cm made of 1mm thickness pirax glass, open on both sides and it has a 3 mm width hole from the top of the tube at 4 cm from the end of the tube allowing argon gas flow.

The internal electrode inside the tube is made of stainless steel. The metal diameter of (1.5 and 8) mm was tapered at the front and 18 cm long, elongated inside the pipe and insulated by Teflon, making a 5 mm distance at the end of the tube from the slot of the needle in order to get the discharge process at the end of the tapered tube with the gas flow that passes through this tube, this electrode connects with the cathode power supply. The other electrode which made of copper was positioned from the outside to the top of the tube, a slice with a thick 1 mm and width 1.5 cm, where this electrode was connected with the anode power supply. A silicon insulator was then placed on the outer copper electrode, in order to prevent direct discharge occurring along the tube. Fig.1 shows the non-thermal plasma needle design.

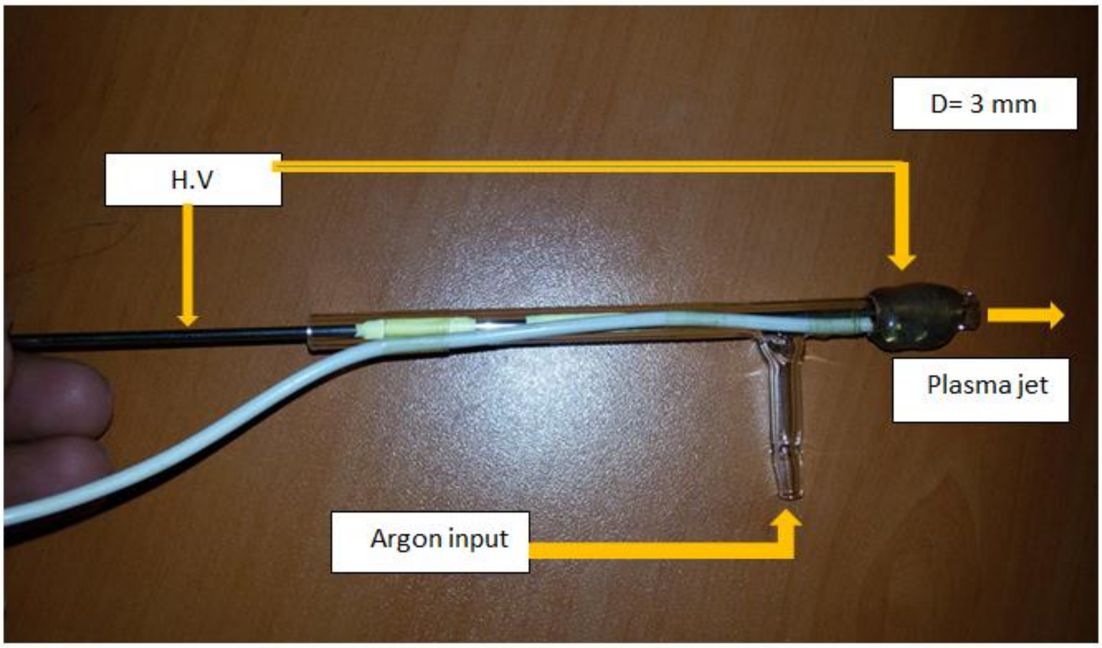


Fig. 1: The non-thermal plasma needle design.

All the instruments of the non-thermal plasma needle system were connected. The system of non-thermal plasma needle used argon gas, with a power supply of 0 to 30 kV, as gas flow rate instrument and metal holder to needle plasma. Fig.2 shows the non-thermal plasma needle system used in this study and its thermal properties were studied.

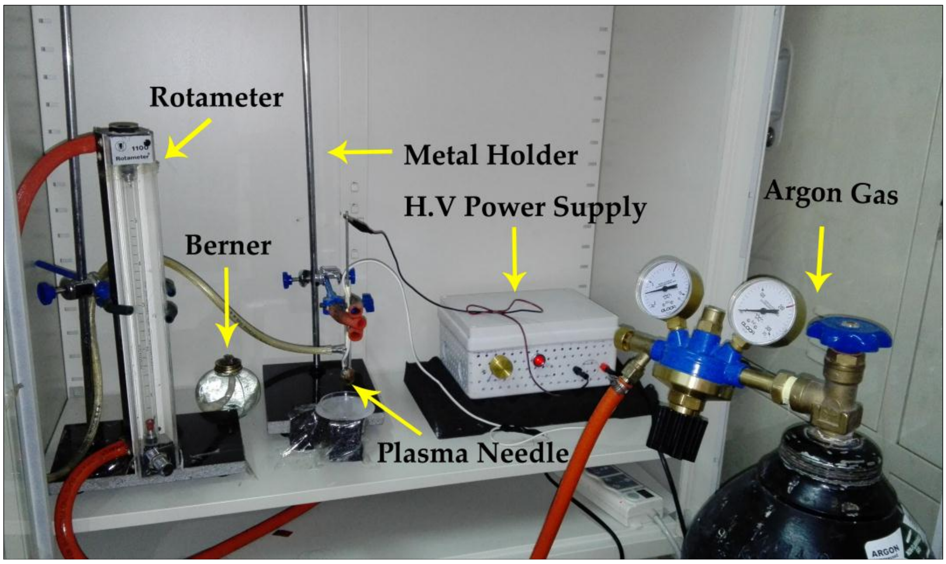


Fig. 2: Image of non-thermal plasma needle system.

Method

The ionized gas temperature has been measured using a digital thermometer that measures the temperature in the range (40°C-232°C) of type (DFP 450 W, Waterproof). The temperature has been measured from different distances along the plasma, where it was measured from the tip of the needle of the device (the thermometer). Fig.3 shows the electrical circuit of the non-thermal plasma needle system.

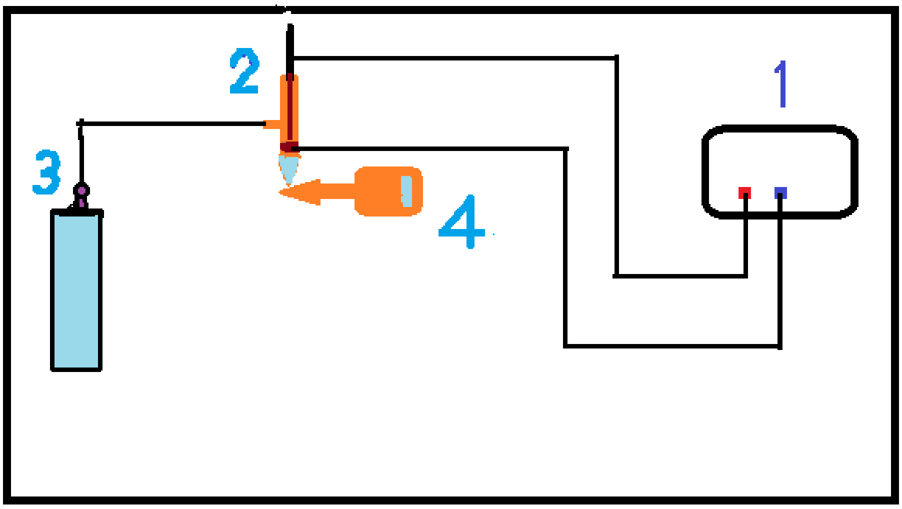
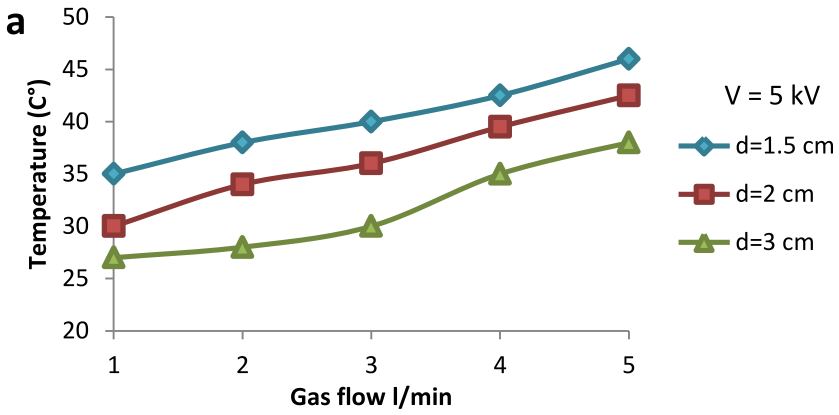


Fig. 3: Schema illustrating non-thermal plasma needle system, where: 1- HV power supply, 2- non-thermal plasma needle, 3- Argon gas, 4- the thermometer.

Results and discussion

The variation of temperature along the experiment operation time is very important especially for biological and medical treatments, also in plasma needle, more electrical energy can be applied to generate energetic electrons during the discharge compared with gas heating [8].

Non equilibrium atmospheric pressure of plasma needle operated with Ar gas was developed successfully. The gas temperature was determined at various distances from the tip of the plasma needle electrode. It was found that the gas flow rate has an effect exerted on the plasma temperature, which is increases with increasing the gas flow rate and decrease with increasing the diameter of the plasma needle as shown in Fig.4 (a, b).



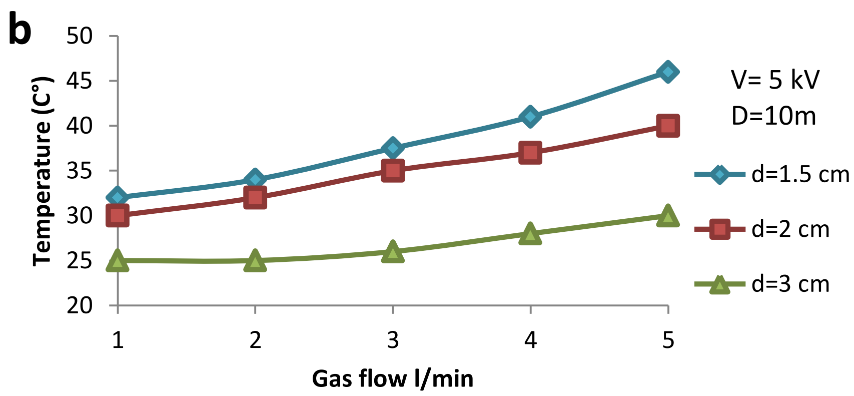


Fig. 4: The relationship between the gas temperature as a function of the gas flow rate for different diameters of the plasma tube (a: 3 mm, b: 10 mm).

When the amount of voltages and tube diameter is installed, the gas temperature increases slightly with the increased of gas flow rate. This is due to the increase in particle velocity.

When comparing the two cases (a, b) we note a slight difference in temperature, where Fig. 4 (a) when the distance 1.5 cm the temperature is 35°C at the flow of 1 liter / minute and begins to increase with increasing flow rate to reach 45 °C at the flow of 5 l / min, while the Fig.4 (b) when the flow is 1 l / min the temperature is 32°C which is less than (a) and starts gradually increasing with the increase of the gas flow rate to reach 41°C at the flow of 5 l / min, and thus we conclude that the diameter of the plasma needle also has an effect on the temperature of the plasma, when increasing diameter of the plasma needle the plasma temperature is decrease.

The distance has an effect on the temperature of the plasma. The greater the distance between the probe and the needle hole lead to lower the plasma temperature, when the voltages value is installed, the gas flow rate and the change in the distance are observed, plasma temperature begins to decrease gradually with increasing the distance. In Fig.5. It can be observed that all curves behave the same behavior to all diameters, the maximum value of the gas temperature is at the needle hole (d = 0) and decreases with the distance away from the hole as the gas loses its temperature to the outside until the temperature is equal to the temperature of surrounding , as shown in Fig.5.

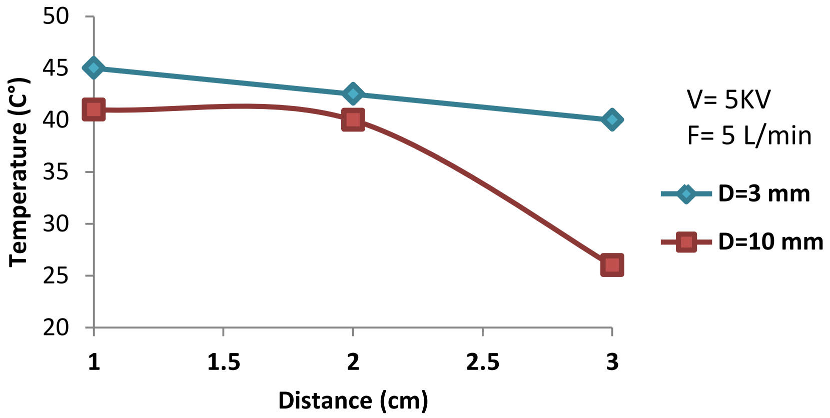


Fig.5: The relationship between the temperature of the gas and distance.

Also, the amount of voltages has an effect on the temperature of the plasma. When the gas flow rate was stabilized to 3l/ min, the distance was stabilized to 2 cm and the voltages are changed, the plasma temperature gradually increases with increasing voltages. This is due to the increased energy of molecules processed by the electric field, as shown in Fig.6.

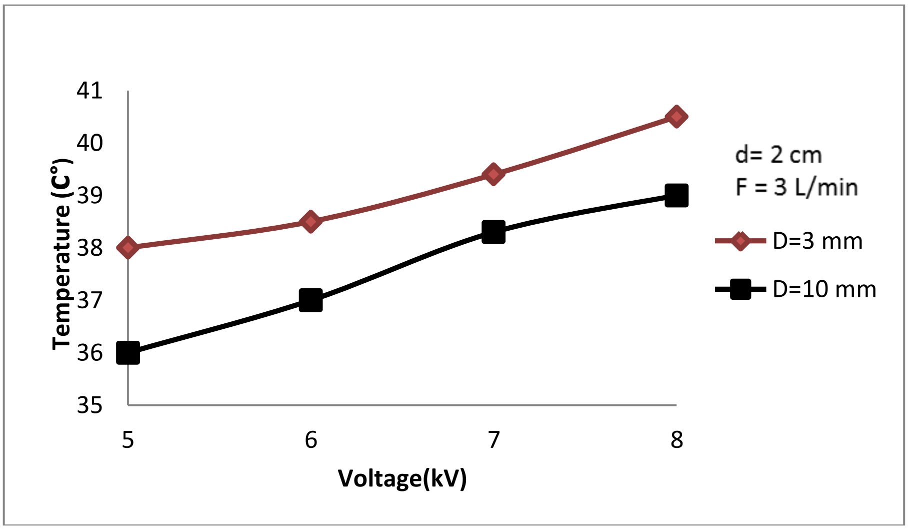


Fig.6: The relationship between voltages and temperature.

From the Fig.6 shows that the temperature of the plasma increases gradually with the increase in voltages, when the voltages at 5 kV the temperature of plasma is 38 °C begins to increase gradually with the increase of voltages to 40.5 °C at 8 kV for the diameter of the plasma needle 3 mm, while the diameter of the plasma needle 10 mm the plasma temperature is relatively low, because increasing the diameter of the plasma needle results in lower plasma density.

Conclusions

From the above results we conclude the following:

1. The current values of the plasma temperature are approach to room temperature, making the non-thermal plasma needle system suitable for medical and biological use without causing any damage.
2. Plasma temperature increases gradually with increased gas flow due to increased number of particles
3. The temperature of the plasma increases with the increase in the applied voltages due to increase in the speed of the particles.

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