Manufacturing of Cold Plasma System and Studies Electrical Characteristic

Ahmed Mahmoud Shihab¹, Hamid Hafidh Murbat² and Ibrahim Karim Abbas³

¹Department of Physics, College of Science, Anbar University. Anbar, Iraq
²Department of Physics, College of Science, Baghdad University. Baghdad, Iraq.
³Department of Physics, College of Science, Anbar University. Anbar, Iraq

ahmedmsh049@gmail.com

Abstract: In this research, the non-thermal plasma system is designed with diameter (10 mm) Argon at atmospheric pressure as well as to be suitable for use in medical and biotechnological applications. The electric description of this system was studied. In this paper, a non-pure argon gas plasma system is designed and manufactured that operates at pressure The normal air. Where the electrical description of this system was studied through the use of values Different voltages and different values of how quickly the argon flows. As the results obtained showed the small value of the electric current consumed by the needle system Non-thermal plasma, where it was in the range of several microns of amps, and the value of the electric current increased with the increase in the gas flow, and the results also showed a breakdown of voltages when the voltage used was 5 kilovolts, which caused a slight decrease in the value of the electric current when the gas flow was 4 liters The minute.

Keywords. Non-thermal plasma, Cold plasma needle, Electric Characteristics.

1. Introduction:
The term "plasma" was first used to describe a collection of charged particles by Tonks and Langmuir in 1929 [1], in their studies of oscillations in electric discharges. However, the most characteristic aspect of the plasma state, the fact that because of the long range of the Coulomb force the charged particles exhibit a collective behavior, was probably first described by Lord Rayleigh [2]. The ancients thought that cosmology consists of four main components: the earth, water, air and fire. A plasma is defined as the fourth state of matter and exactly fire. It is an ionized gas containing free moving charge carriers: electrons and ions [3].

Plasma physics has played a major role in the development of many contemporary physics, and is important in studying problems in fields such as astrophysics, atomic physics, chemistry, life sciences, molecular physics, hydrodynamic magnetic power generation and atmospheric physics [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 are reacting by moving molecules [4].
It can be said that the state of matter depends on the local kinetic energy of the particles. Therefore, at a certain temperature, the difference between the kinetic energy of these particles and the potential energy has a standard from which the state of the material can be known [5].

It is possible to convert a solid body into a liquid by adding thermal energy to overcome the energy of bonding between atoms or molecules, which is the energy called the potential energy of fusion, as well as converting the liquid into gas. The energy required for the conversion is known as the potential energy of evaporation. In the form of phases, as the electrical parity is preserved in the insides and outputs, so these two transformations are considered to be phase transformations. As for the transformation to the state of the plasma, it takes place when adding enough heat energy to separate the atom's electron from its nuclei, which is known as the ionization energy, and the ionization is partially done in the gas when the energy required for ionization is available and this happens gradually. It is noted here that the transformation takes place from electrically neutral components to charged components, so the transformation to the state of the plasma is not considered a phase shift [6].

Plasma can be produced for a very wide range of pressure and temperatures, it is possible to produce plasma at low pressure or at atmospheric pressure by using various energy sources such as mechanical, thermal, chemical, radiative, nuclear or by high voltage projection and use all these means to overcome the electron binding energy from atoms or molecules of the gaseous medium so the molecules of the gaseous medium are separated into a group of ions and electrons as well as neutral gas molecules - charged and other elements, so plasma is a chemically active environment that collects particles and radiation of a diverse nature, examples of plasma in nature are stars and lightning, as they are all found in the state of plasma (natural plasma) and laboratory plasma can be produced (industrial plasma), and plasma interference in many fields, including medical and industrial [7].

Plasma can be generated in various ways, and the most common way to generate plasma is by electrical discharge in neutral gases. This is done by placing a high voltage difference between two electrodes on a gas at a certain pressure, which leads to the generation of an electrical discharge between the anode and the cathode in the gas. Also, plasma can be produced in vitro by heating a gas at a pressure less than the usual atmospheric pressure to the extent that the kinetic energy of the particles of this gas becomes sufficient to cause the ionization process through inelastic collisions between them [8,9].

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 $10^5 K^°$. 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. In this type of plasma ions and neutral particles temperature surrounding itself, the degree of electron temperature rises much bigger than any other particles ($T_e >> T_i \approx T_n$). 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 [10].

2. Electrical Characteristics

In order to generate viable plasma, it must be The rated voltage is greater than the breakdown voltage of the gases. When the voltage exceeded the breakdown voltage Gases lose their insulating properties and turn into conductive gases. The requirement for self-feeding (support) (Self) is given by the following formula: [11].

$$1 - \gamma (e^{a d} - 1) = 0$$

$$e^{a d} = \left(1 + \frac{1}{\gamma}\right)$$

Secondary emission factor $\gamma$, Passion constant B, Distance d,
Voltage $V_p$:
The breakdown voltage of a gas can be determined by the Paschen law, which gives the breakdown voltage as a function of the product of the gas pressure ($p$) and the distance between the electrodes ($d$) as follows:

$$V_p = \frac{apd}{\ln(pd)+b}$$

$V_p$: breakdown voltage, $p$: gas pressure, $d$: the distance between the anode and the cathode, $a$ and $b$ constants.

Equation (3) shows the relationship between the breakdown voltage and pressure, whether it is at low pressure or normal atmospheric pressure (the collapse between two parallel plates as a function of pressure and the distance between the two plates). From equation (3) it is clear that the breakdown voltage depends only on the product of multiplication Gas pressure and the separation distance of the gas used, as well as the nature of the cathode, when both pressure and distance are proven [12].

![Paschen Curved of He](image1.png)

Figure 1. Paschen Curved of He.

3. Experimental setup
Non-thermal plasma needle is designed where the device is cylindrical-shaped tube, inner diameter of 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 (8) mm was tapered at the front and 17 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, the figure 2' shows the non-thermal plasma needle design.
4. Method

Voltages are measured using a Probe Fluke probe type for measurement range (0-40) kV and (1/1000) turn. The electrical current was measured by segmentation voltage by connecting the resistor with (R = 8KΩ) to the cathode path and measuring the voltages on both ends of the resistor using a device (digital) and calculate the current pass from which. Where different values are taken from voltages and divided by resistance, they are extracted Current values. Two voltage values depend on (4.9, 8) kV with changing gas flow values (1-5 l/min) to show the effect of the change in gas flow on the voltage values at the voltage. Then, evaluate the electrical current used in this system, figure 4' Schema of non-thermal plasma needle system illustrating the connection of an electrical circuit.

Figure 2. 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. Figure 3’ shows the non-thermal plasma needle system used in this research and its thermal properties were studied.

Figure 3. Image of non-thermal plasma needle system.
5. Results and Discussion
Non equilibrium atmospheric pressure of plasma needle operated with Ar gas was developed successfully. It has been found that the rate of gas flow has an effect on the amount of current, which increases with increasing gas flow rate. It was found that when the rated voltage is less (less than 5 kV), the current flowing into the system is very small, by about several microns, and increases slightly with projected voltage, then increases sharply at the point where the system begins to produce plasma. Then, the current values continue to increase to a point that depends on the amount of runoff gas flow.

Figure 5 shows the relationship between the discharge current to the plasma needle and the rated voltage as a function of the rated voltage, for two different values of the argon flow rate which are (3, 5) l/min.

This can be explained by the fact that when the voltages are low and insufficient for ionization events of the gas molecules, current values are limited and limited to the displacement current resulting from some initial ionization of gas particles. As voltages increase, the energy supplied to the particles increases from the electric field, and when this energy reaches the necessary amount for secondary ionization events for particles, the area close to the anode becomes a collapsing region, so all particles passing by Secondary ionization, so the region between the two poles becomes a fully ionized region, so the current value will rise to a point Stability and continues to remain almost constant with increased voltages [13].
Figure 6. Shows the relationship between the gas flow rate and current.

The figure 6 shows the relationship between the discharge current as a function of the flow velocity of the flowing Ark gas during the needle. The amount of current increases with increasing gas flow velocity, and this is interpreted as the increase in gas flow velocity decreases the time that particles spend inside the chamber (inside the ionization area) and this needs to spend more energy to ionize the particles and generate plasma and then the increase in the number of ions leads to an increase in the current [14].

6. Conclusions

From the above results we conclude the current values of the current amount are few, which makes the non-thermal plasma needle system suitable for medical and biological use without causing any damage. And amount of current increases gradually as the gas flow increases due to the increase in the number of particles. As a result of the amount of current increases as the applied voltage increases due to the increase in particle velocity. Finally, highest electric current value (8.7 μA) occurs when the voltage used is (6 kV), while the highest electric current value (6.2 μA) occurs when the gas flow velocity (3 l/min).

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References

[1] Van Der Laan E P, Stoffels E and Steinbuch M 2006 Development of a smart positioning sensor for the plasma needle Plasma Sources Sci. Technol. 15 582
[2] Misra N N, Schlüter O and Cullen P J 2016 Cold plasma in food and agriculture: fundamentals and applications (Academic Press)
[3] Vera E, Dulcé-Moreno H J, Contreras de la Ossa G J and Peña G 2011 Nitruración De Un Acero Al Carbón Mediante Descargas De Barrera Dieléctrica A Presión Atmosférica Rev. Colomb. Física 42 410
[4] Abbas I K and Hussein M U 2018 the Effect of Non-Thermal Plasma Needle on Staphylococcus Aureus Bacteria 18 5075
[5] Bellan P M 2008 Fundamentals of plasma physics (Cambridge University Press)
[6] Eliezer S and Eliezer Y 2001 The fourth state of matter: an introduction to plasma science (CRC Press)
[7] Julák J, Scholtz V and Vaňková E 2018 Medically important biofilms and non-thermal plasma World J. Microbiol. Biotechnol. 34 178
[8] Shintani H 2016 Inactivation of bacterial spore, endotoxin, lipid A, normal prion and abnormal prion by exposures to several sorts of gases plasma Biocontrol Sci. 21 1–12
[9] Shishoo R 2007 Plasma technologies for textiles (Elsevier)
[10] Kieft I E 2005 Plasma needle: exploring biomedical applications of non-thermal plasmas (Technische Universität Eindhoven)
[11] Bonizzoni G and Vassallo E 2002 Plasma physics and technology; industrial applications Vacuum 64 327–36
[12] Schutze A, Jeong J Y, Babayan S E, Park J, Selwyn G S and Hicks R F 1998 The atmospheric-pressure plasma jet: a review and comparison to other plasma sources IEEE Trans. plasma Sci. 26 1685–94
[13] Bureyev O A, Surkov Y S, Spirina A V, Schutze A, Jeong J Y, Babayan S E, Park J, Selwyn G S, Hicks R F, Bonizzoni G, Vassallo E and Kieft I E 2002 Characteristics of cold atmospheric plasma source based on low-current pulsed discharge with coaxial electrodes IEEE Trans. plasma Sci. 64 327–36
[14] Abbas I K, Hussein M U and Murbat H H 2017 The Study of Electrical Description for Non-Thermal Plasma Needle System Iraqi J. Sci. 58 1447–53