Argon plasma needle source

Hammad R. Humud , Ahamad S. Wasfi , Wafaa Abd Al-Razaq, Mazin S. El-Ansary

Department of Physics, College of Science, University of Baghdad

E-mail: dr.hammad6000@yahoo.com

Abstract

Non thermal argon plasma needle at atmospheric pressure was generated. The experimental set up is based on very simple and low cost electric components that generate electrical field sufficiently high at the electrodes to ionize various gases, which flow at atmospheric pressure. The high d.c power supply is 7.5kV peak to peak, the frequency of the electrical field is 28kHz, and the plasma power less than 15W. The plasma is generated using only one electrode. In the present work the voltage and current discharge waveform are measured. Also the temperature of the working Ar gas at different gas flow and distances from the plasma electrode tip was recorded.

Key words
Plasma needle,
non- thermal plasma

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مصدر توليد ابرة بلازما الاركون

حمد رحيم حمود، أحمد سلمان وصفي، وفاء عبد الرزاق، مازن سلمان الانصاري

قسم الفيزياء، كلية العلوم، جامعة بغداد

الخلاصة

تم توليد ابرة بلازما الاركون غير الحرارية وتحت الضغط الجوي. باستعمال مكونات الكترونية بسيطة وواطئة الكلفة. لها القدرة على توليد مجال كهربائي عالي عند الاقطاب يكفي لتأين الغازات المختلفة والمتدفقة عند الضغط الجوي. ولدت البلازما التي تم دراستها بفولتية متناوبة عند الاقطاب 7.5 كيلوفولت من القمة الى القمة وكانت قدرتها 15 واط وتردد المجال المسلط 28 كيلو هرتز. قدم هذا العمل معلومات عن قياس الفولتية والتيار اللذان استعملا في توليد البلازما. كذلك تم قياس درجة حرارة الاركون المتدفق بمستويات تدفق مختلفة من نهاية القطب الكهربائي.

Introduction

The plasma needle is a type of non-thermal atmospheric glow discharge, it has a single electrode configuration and is operate by different noble gas (He-Ar), important properties of this type of plasma are that it operate at near room temperature, the plasma does not cause any thermal damage to articles it comes in contact with. This characteristic was open up the possibility to use this plasma for treatment of the heat sensitive materials. Atmospheric pressure discharge plasma is of great interest because of their low costs and simplified operation[1]. Non thermal (cold plasma), that is not inthermodynamic equilibrium, which means that the temperature of molecules, atoms and ions does not match the temperature of the electrons [2]. Due to mentioned characteristics of non-thermal plasma make it used for activating the surface of polymers, growing solar cells and etching materials [3, 4]. Several applications such as treatment of living cells [5], sterilization [4], blood coagulation, wound healing, bacteria in activation [6, 7, 8], tooth bleaching [9] and air purification [8].

Among the various plasma sources reported, Ar plasma jet is very effective for the sterilization of micro-organism. It was observed that Ar plasma source showed stronger emission intensity of reactive radicals and better killing effect than the He plasma source [6].

There are not so many sources that can be applied directly and with high precision to the treated area, our research aimed to generate a flexible plasma torch and non-destructive plasma for direct treatment of thermal sensitive target. And also aimed to generate plasma may be of interest for researchers who need to make such discharge. We studied the experimental conditions under which this plasma can be generated by electrical fields with a frequency of 28kHz generated by 12V dc supply voltages and using only one electrode as the plasma sustaining electrode.

Experiment setup

a-**Plasma torch**

The plasma torch (shown in Fig. 1) is consisting from 10cc glass syringe adapted to a hallow stainless steel needle with inner diameter (1.04mm) from one side and the working gas (Ar) into other side through Teflon gas fitting. The needle connected directly to the high voltage transformer with the plasma electrode. The Ar gas is directed to the needle through the syringe and mixes with ambient air around the tip of the needle.

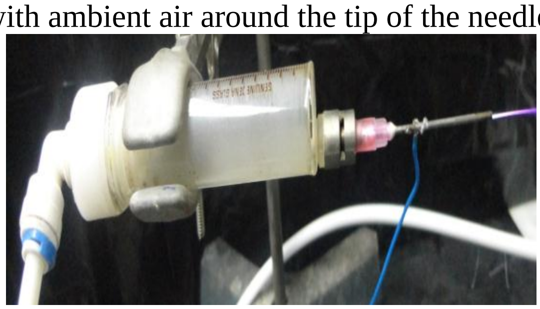


Fig. (1): Plasma torch

b-Experiment circuitry

The electric circuit used to generate the plasma is shown in Fig. (2). The design based on high frequency resonant flyback transformer, which is winded on ferrite core rod. One end of the primary winding is connected to 12V dc power supply while the other end is connected to the drain of the Metal-Oxide Semiconductor Field Effect Transistor (MOSFET) IRF 540A. The source of the transistor is connected to ground while the gate is derived by the feedback winding of the flyback transformer. One end of the secondary wind transformer is connected to ground while the other end is connected to the needle. The resonant frequency that the transformer will run at is determined by the inductance and capacitance of the transformer primary coil. The fallowing Eq. was used to determine the resonance frequency:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

where

f is the frequency in Hz.

L is the inductance in Henry.

C is the capacitance of the coil in Farad

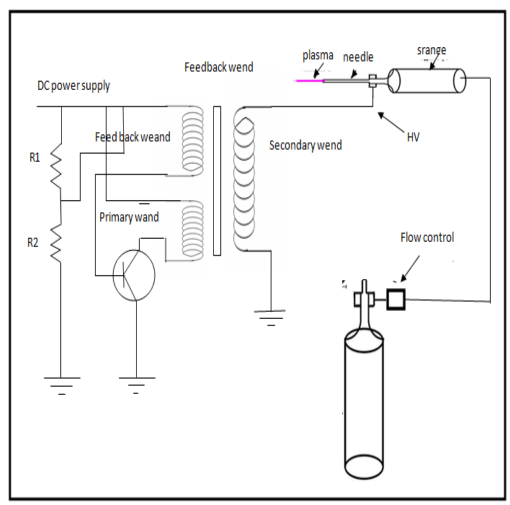


Fig.(2): Schematic diagram of a non-thermal plasma source

Principle of operation of power eneration

When the power is applied, the transistor will conduct the current passed through resistors R1 and R2 to the flyback primary, causing it to induce current on the secondary, and at the same time, on the feedback winding. This feedback current will trigger the transistor to stop conducting and as the magnetic field in the ferrite core collapses a large high voltage (HV) spike will appear on the secondary winding, but now there is no feedback current to keep the transistor off, so it will once again conduct, and the cycle will repeat itself at a natural frequency that puts the transformer in resonance. One of the advantages of having a feedback winding is that the circuit becomes dynamic. The frequencies of operation are automatically adjusted to resonance.

c-Plasma characterization

(1) **The axial gas temperature**

Since the kHz frequency emission of the plasma needle was influencing this measurement while using a thermocouple, the axial gas temperature was measured with simple mercury thermometer. The heat sensitive part of the thermometer was placed at different distance from the end of the needle [10], while the Ar gas was flowing at different flow rate through the needle.

(2)Electrical characterization

The measurement of voltage and current offers the possibility to characterize the plasma properties mainly the plasma power. The power P is given as [10]

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

where u being the voltage, I the current and T is the oscillation period. A home-made high voltage probe with an attenuation factor of 1000 with an oscilloscope (Gos-652G 50MHz) was used for measuring voltage waveform and the current was measured by a Tektronaxs current probe A6302 with Am503 current probe amplifier, and monitored by the oscilloscope.

Results and Discussion

a-Thermal properties

Non equilibrium atmospheric pressure plasma needle operated with Ar gas was developed successfully. The gas temperature which was determined by mercury thermometer at various distances from the tip of the plasma needle electrode, for various Ar gas flow rate is shown in Fig.(3).

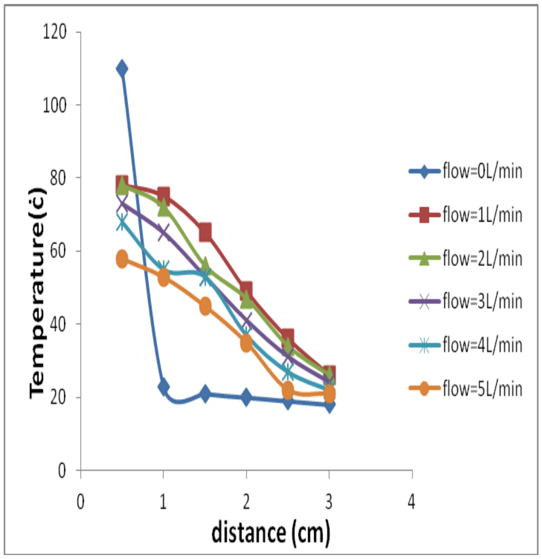
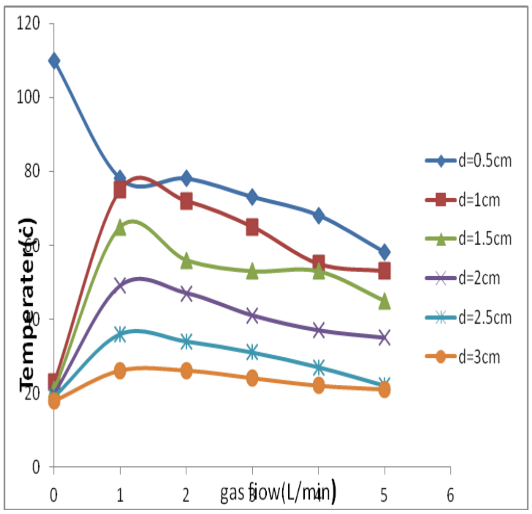


Fig (3): Dependence of the gas temperature on the axial distance between the thermometer and the tip of the needle for various gas flow rates

This temperature is below than 80ºC at distances shorter than 10 mm from the needle tip for all gas flow rates, and the gas temperature decreases with increasing the distance from the needle tip, and with higher gas flow rates. This is because, the higher gas flow rate can transfer the heat from the plasma needle away more than the lower flow rates [11]. The sudden increase of temperature at no gas flow and at a distanced shorter than 10mm is due to arc discharges between the plasma electrode and the thermometer. At certain gas flow rate the gas dynamic flowing do not permit arc generation [3]. The optimum flow rate that gives maximum gas temperature at different distances is shown in Fig.(4), it is found around 1.3 l/min. The temperature behavior for gas flow rate lower than 1.3l/min is due to high transfer efficiency of the energy from the plasma needle generator to the plasma. For flow rate rather than 1.3l/min the temperature decreases because the gas cooling is higher at high gas flow rates [3].



Fig(4): Dependence of the gas temperature on the gas flow rate at various distance

b-Electrical properties

The voltage, and current wave form is shown in Fig.(5). The voltage was measured at the ends of the secondary coil of the flyback transformer, from the figure we can see that the voltage have sinusoidal wave form with frequency of 28kHz. This frequency is near the resonant frequency of the secondary circuit of the flyback transformer which calculated from the RLC values for the secondary coil.

The measured voltage at the ends of the secondary coil is 7.5kV peak to peak. The current waveform has four damped oscillations of the applied voltage, with 35μs cycle.

This behavior may be due to the capacitive coupling of the circuits with the discharged gas [12]. The voltage and the current show no spiky lines which indicates that the discharges are homogenous glow [12] also from the figure we can see that the current leading the voltage, which demonstrates the capacitive character of the discharge [13]. Fig.(6) shows the estimated power according to the voltage and current waveform the peak power wave about 63W and the average power is about 15W.

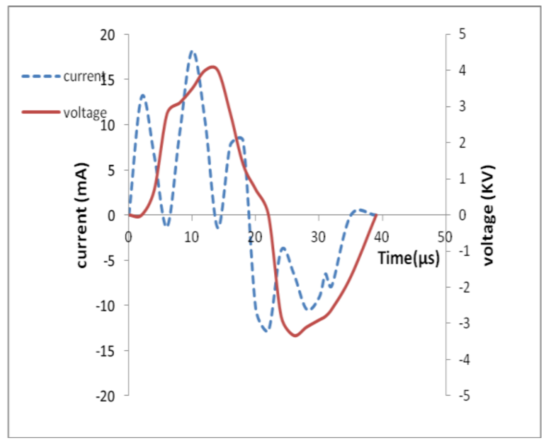


Fig (5): Voltage and current wave form

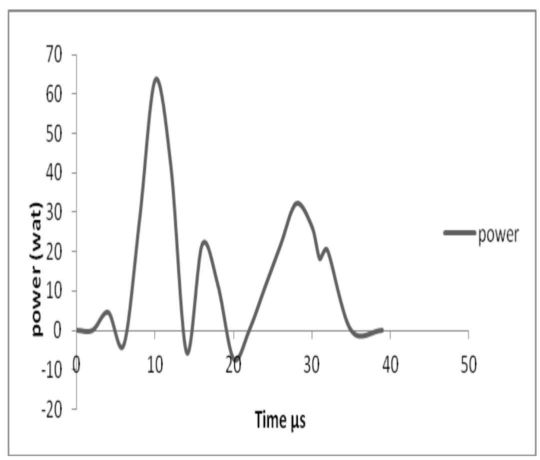


Fig (6): The measured power according to the voltage and current waveform

Conclusions

The present work concluded the following:

1-The plasma generator was built using only general purpose component, that are ready available, the unit is easy to set up and operate.

2-A non-thermal plasma torch was built to operate at atmospheric pressure.

3-The paper outlined how the certain electrical parameters (voltage and current waveform plasma power) measurements were achieved.

4-At distances longer than 2cm from the tip of the needle the plasma is thermally non aggressive, its temperature being lower than 55ºC, therefore can be used in medical.

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