Construction of the Non-Thermal Helium Plasma Jet using Two Electrodes and studying its Characteristics

Riam A. Hammoodi[1], Mohammed K. Khalaf[2], Ahmed K. Abbas[3]

[1, 3]University of Wasit, College of Science

[2]Ministry of Science and Technology

Abstract: ***In this work, a home- made plasma jet system has been constructed. The system which used in this work was a dielectric barrier discharge (DBD) type atmospheric pressure plasma jet (APPJ). It was applied to generate a non-thermal plasma using an alternating current (AC) power supply (providing voltages 4,6,8 and 10) kV_{p-p} and frequencies up to 20 kHz) with one types of noble gas(helium). The system was based on two electrodes configuration, where the configuration based on double-ring electrodes structure. Each configuration used two types of Pyrex tube with wall thickness of 0.8 mm and then when we changed to a pyrex tube with (1) mm we noticed no plasma was generated and studying all the characteristics***

Keywords: Plasma, DPD, electrodes, cold, atmospheric, the non-thermal, helium, jet

1. Introduction

Plasma in nature, such as sun, aurora borealis and lightning is always fascinated by people [1]. The first investigations in electrical gas dis- charges are submitted by Ernst Siemens [2], who in 1857 offered a novel type of electrical discharge, which produced ozone (O3) from oxygen or air. Two coaxial tubes made of glass are used to start the discharge in a gap between the tubes and an electric field is applied between coaxial ex- ternal electrodes to produce electrical breakdown. The electric current is compelled to pass through the glass walls, acting as dielectric barriers.

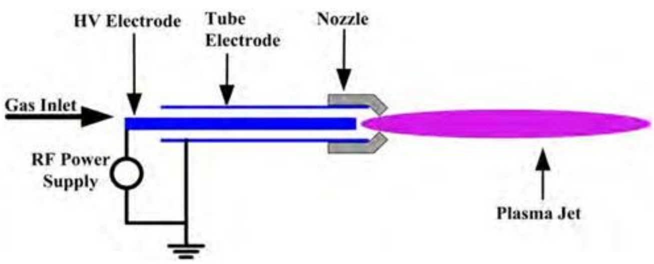
The discharge is ordinarily mentioned as the dielectric barrier discharge (DBD) [3]. In 1928, an American physicist Irving Langmuir [4], the Nobel laureate, proposed that the word plasma will be used to appoint that portion of an arc sort discharge, which the densities of electrons and ions are high but significantly equal. This discharge carries many varied particles such as electrons, ions, excited atoms and molecules which is similar to the blood plasma method that transports red and white blood cells [5].

Atmospheric Pressure PlasmaJets

Atmospheric pressure non-thermal plasma jet (is a great plasma type that has been actively studied through the earlier decade [6]. This device normally consists of a dielectric tube made of quartz, Pyrex, or ceramic tube with an electrode inserted inside the tube or wrapped around it. Various noble gases such as argon, helium and nitrogen are fed into the dielectric tube and occasionally are mixed with a small percentage of oxygen gas to increase the reactive species [7,8].

Dielectric Electrode Jets

The dielectric electrode jets, as shown in figure can be operated by a power of radio frequency supply of 13.56MHz. It consists of internal and external electrode [9]. The external electrode represents the tube and it is grounded whereas the internal electrode is coupled to the power supply. Helium gas is fed into the tube and mixed with reactive gases [10]. The RF power which delivered to the plasma jet is very high (between 50 and 500W) **[11].**



Dielectric Barrier Discharge Jets

Consists of a dielectric tube with double metal ring electrodes which located at the external side of the tube and these electrodes are connected to the power supply [12, 13]. different gases are used in this device like helium, argon, the second configuration as shown in figure (3.2)(b) was based on a double-ring electrode configuration, which have two aluminum rings electrode covered the external Pyrex tube. The distance between two electrodes was fixed to 12 mm and the distance between downstream electrode and the nozzle of the Pyrex tube was fixed to 4 mm. The upstream electrode was connected to power supply and the downstream electrode was grounded [14].

Double-ring electrode configuration with wall thickness of 0.80mm

Double-ring electrode configuration with wall thickness of 1mm

2. Measurement of the Characteristics

Measurement of the Plasma Plume Length

It's the distance between the tip of the plasma plume and the edge of Pyrex tube. This indicates that the higher gas flow rate and applied voltage lead to longer plasma plume, The voltages we studied were (4, 6, 8 and 10) kVp-p and the frequency was up to 28HZ using helium gas we noticed that the plasma plume is increased by increasing the flow and also increasing the voltages also increase the plasma plume as shown in the figures

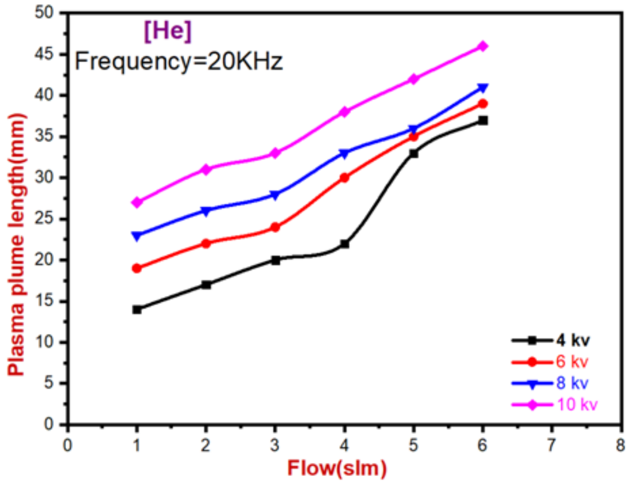


Fig this figure shows the relationship between the plasma plume and the flow.

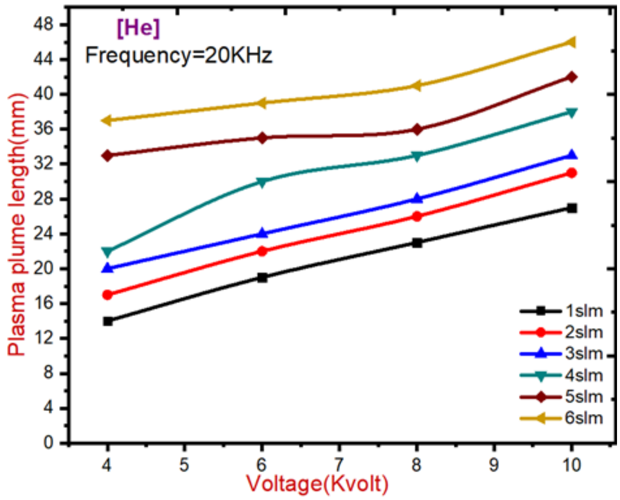


Fig this figure shows the relationship between the plasma plume and the source voltages

Plasma Plume Length (mm)	Flow (slm)
14	1
17	2
20	3
22	4
33	5
37	6

Fig this figure shows the relationship between the plasma plume and the flow rate at voltage at 4kVp-p.

Plasma Plume Length (mm)	Flow (slm)
19	1
22	2
24	3
30	4
35	5
39	6

Fig this figure shows the relationship between the plasma plume and the flow rate at voltage at 6kVp-p.

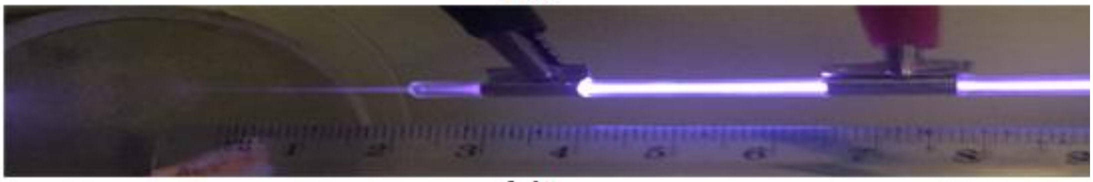
Plasma Plume Length (mm)	Flow (slm)
23	1
26	2
28	3
33	4
36	5
41	6

Fig this figure shows the relationship between the plasma plume and the flow rate at voltage at 8kVp-p.

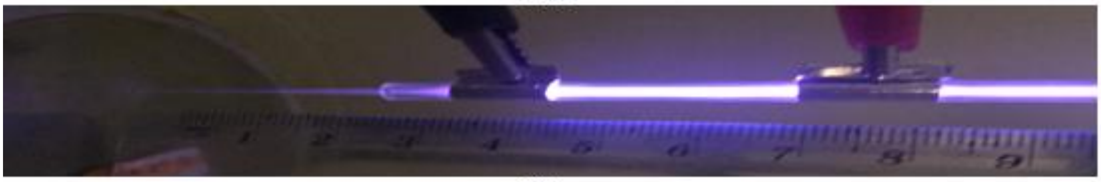
Plasma Plume Length (mm)	Flow (slm)
27	1
31	2
33	3
38	4
42	5
46	6

Fig this figure shows the relationship between the plasma plume and the flow rate at voltage at 10kVp-p.

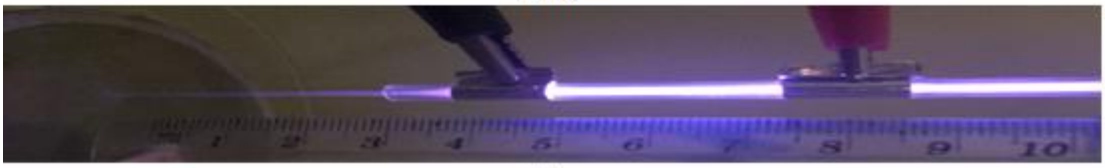
1 slm



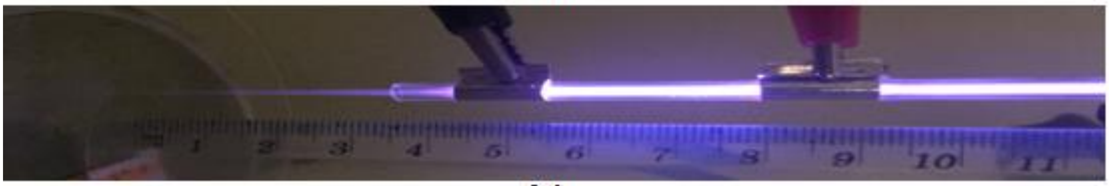
2 slm



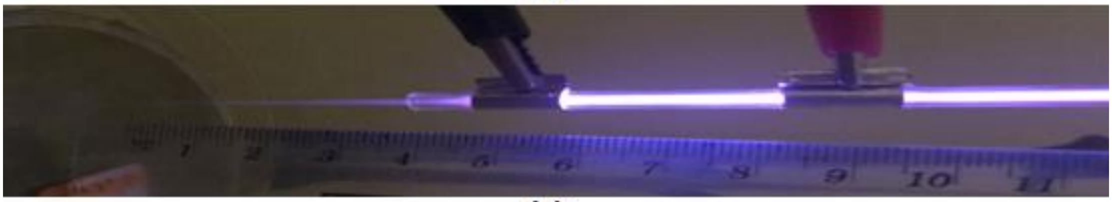
3 slm



4 slm

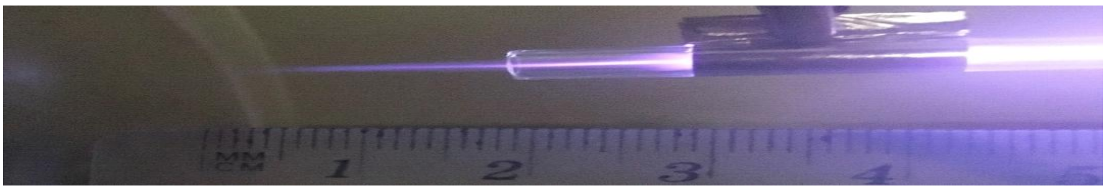


5 slm

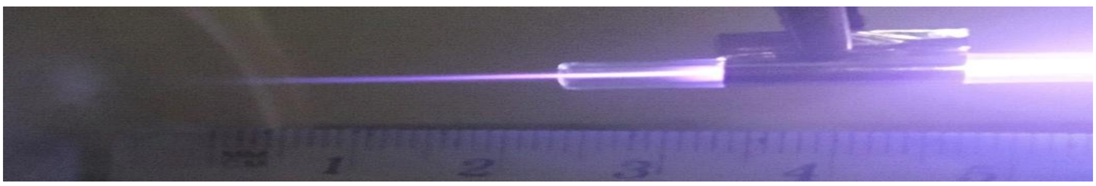


6 slm

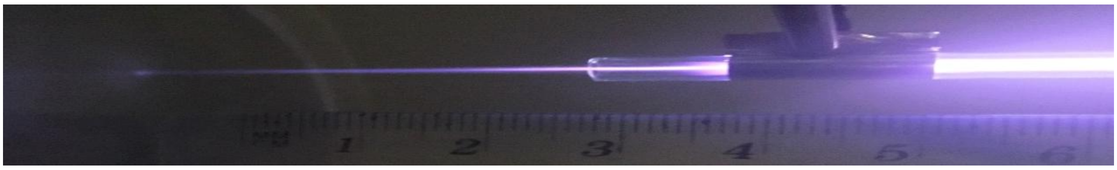
Fig photographs show the plasma plumes for different helium flow rates at 4kVp-p.



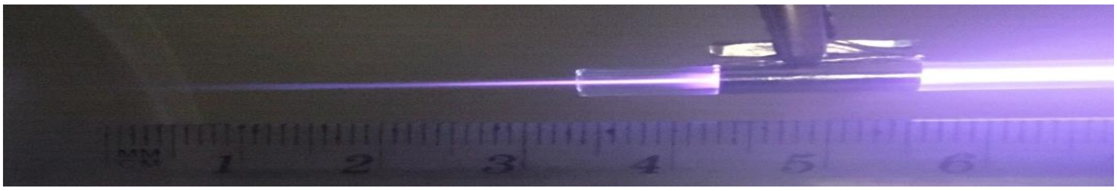
1 slm



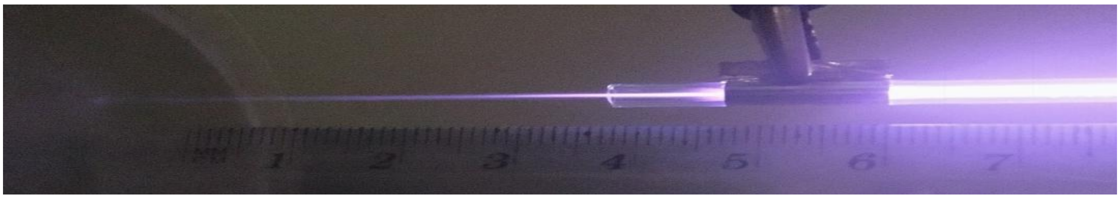
2 slm



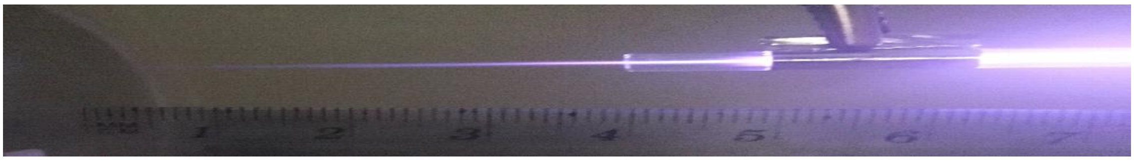
3 slm



4 slm

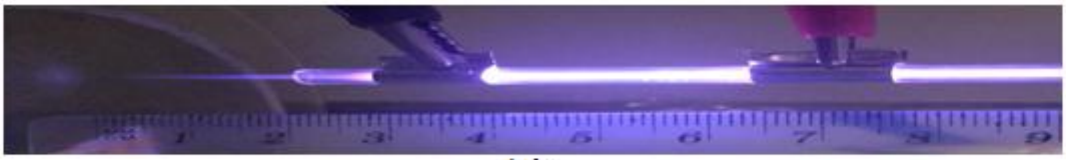


5 slm

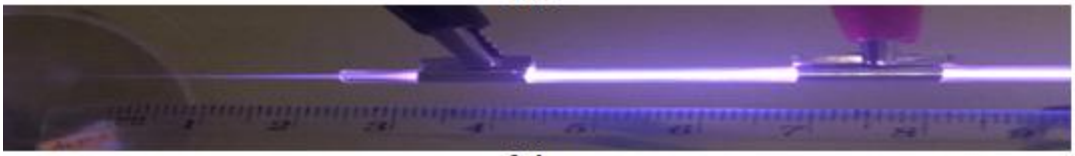


6 slm

Fig photographs show the plasma plumes for different helium flow rates at 6kVp-p.

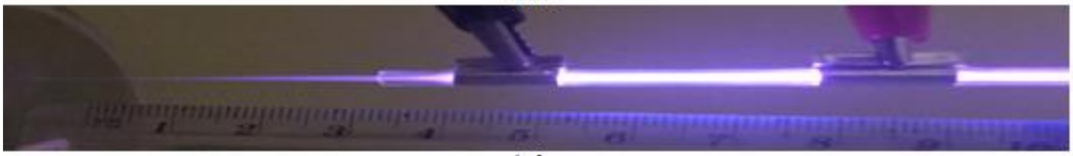


1 slm

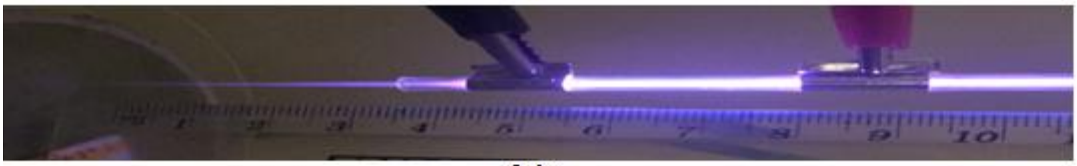


2 slm

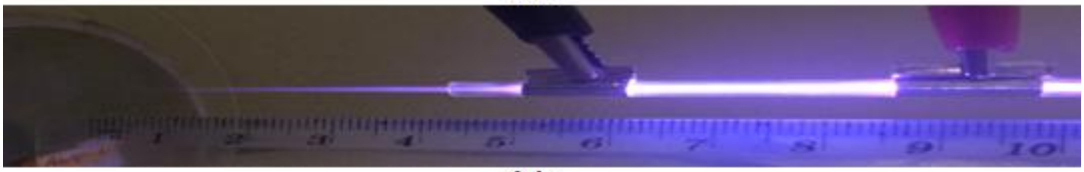
3 slm



4 slm



5 slm



6 slm

Fig photographs show the plasma plumes for different helium flow rates at 8kVp-p.

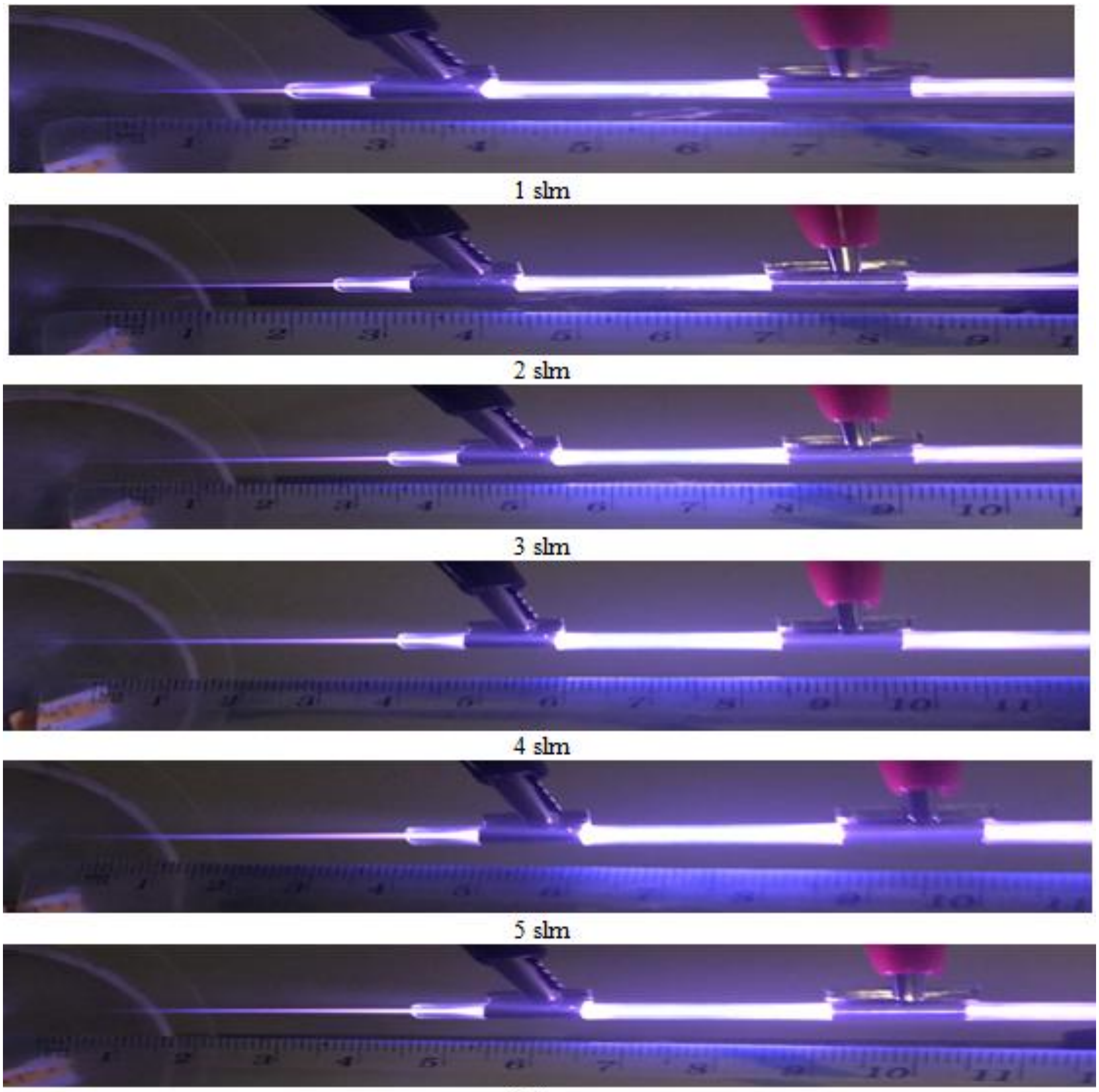


Fig photographs show the plasma plumes for different helium flow rates at 10kVp-p

Plasma Jet Temperature Measurement
It can be measured by using the mercury thermometer where the heat sensitive part was located at various distances from the end of the tube nozzle with different gas flow rate

It is observed that the helium plasma jet temperature decrease more than argon with increased plasma plume length. In addition, with increasing gas flow rate, the plasma jet temperature decreased with helium in time until it fixed at (120,150,180) sec. By increasing source voltages the temperature increases

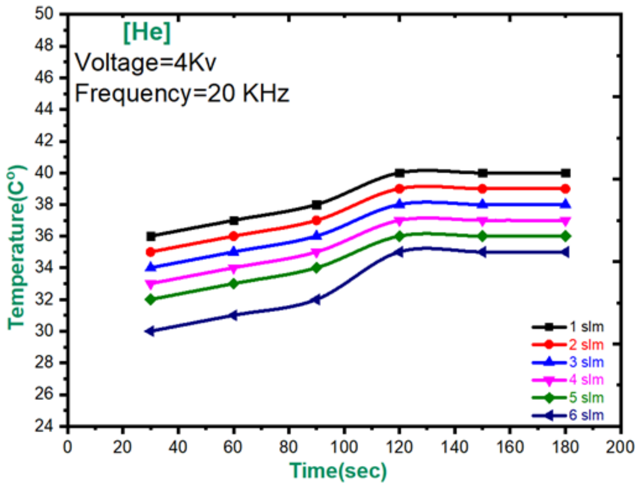


Fig this figure shows the relationship between the temperature as a function of time for different helium flow rates (voltage =4kVp-p).

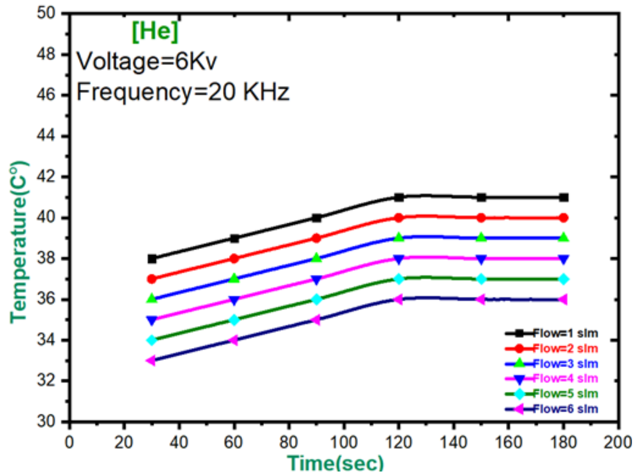


Fig this figure shows the relationship between the temperature as a function of time for different helium flow rates (voltage =6kVp-p)

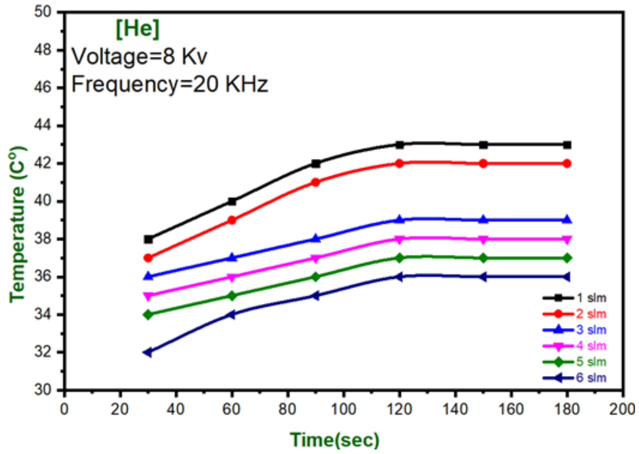


Fig this figure shows the relationship between the temperature as a function of time for different helium flow rates (voltage =8kVp-p).

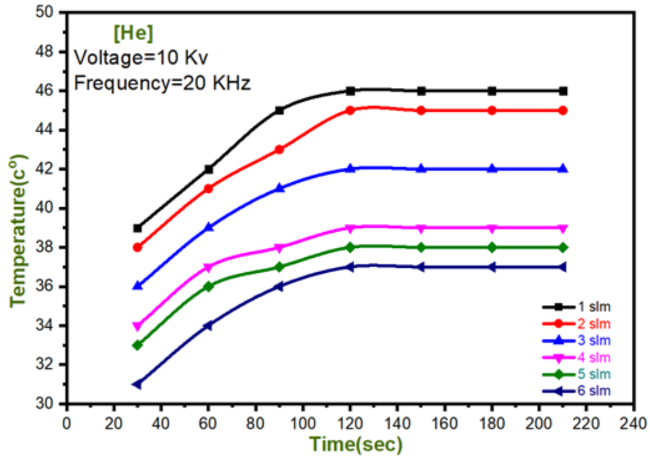
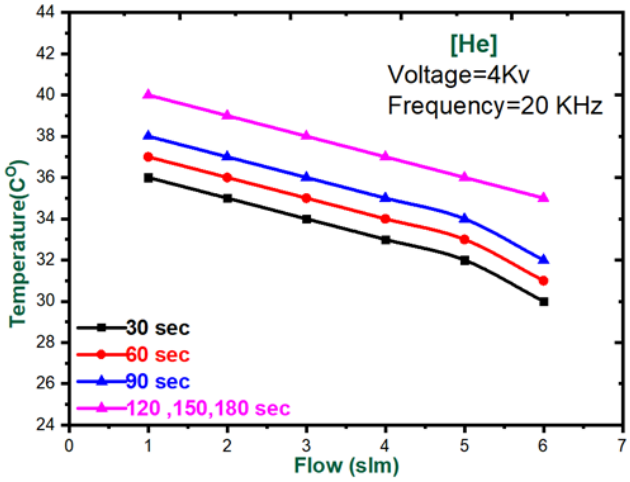
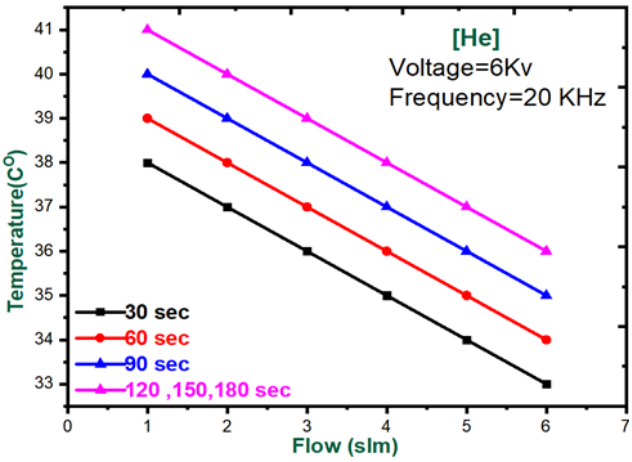


Fig this figure shows the relationship between the temperature as a function of time for different helium flow rates (voltage =10kVp-p).





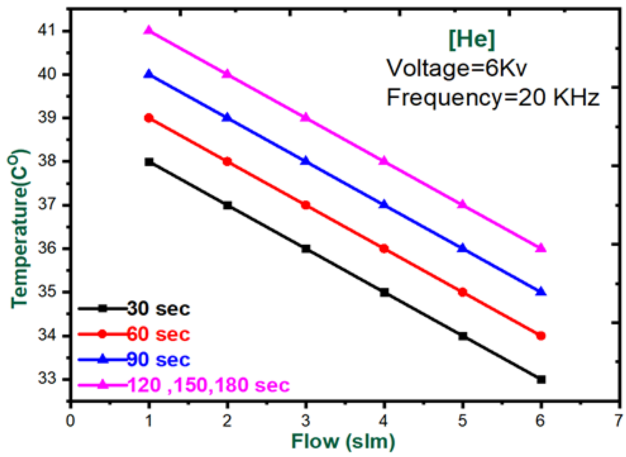
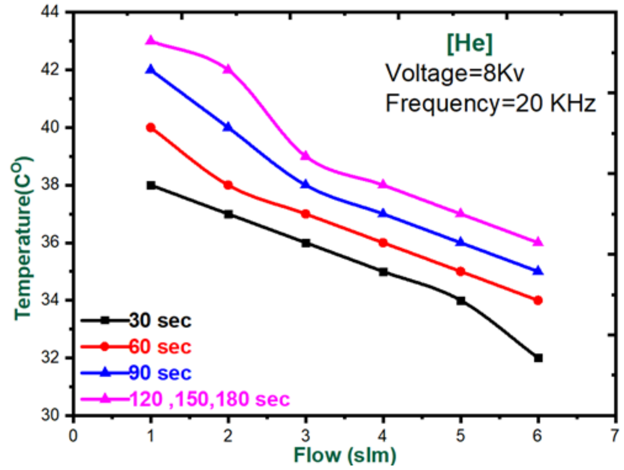
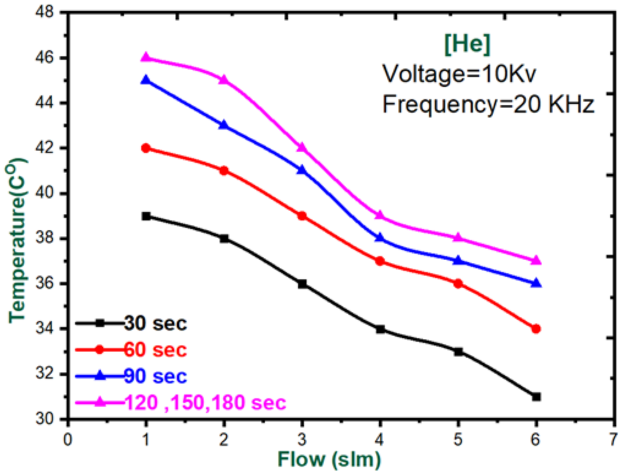


Fig this figure shows the relationship between the temperature and the flow rate





3. Discussion

Ahome-made non-thermal DBD plasma jet has been successfully built and we studied its characteristics

The reduction of Pyrex tube wall thickness has an effect on the plasma system and reduce the temperature of plasma jet

The plasma plume length depends on the source voltage type, flow rate , if we used the same gas

The plasma jet temperature which generated using double ring electrode configuration was close to room temperature.

The electron temperature for helium plasma jets decreased with higher gas flow rate, while increased with higher voltage. The plasma jet temperature increases with increasing time in argon more than helium and decreased with higher flow rate in helium plasma jet more than in argon that the higher gas flow rate and applied voltage lead to longer plasma plume the width of the plasma plume in helium increased

References

[1] U. Kogelschatz, "*Dielectric-Barrier Discharges: Their History, Discharge Physics, and Industrial Applications*," Plasma Chemistry and Plasma Processing, Vol. 23, No. 1, pp. 1–46, 2003.

[2] J. Townsend, "*Motion of Electrons in Gases*," Journal of the Franklin Institute, Vol. 200, No. 5, pp. 563–590, 1925.

[3] Schutze, J. Jeong, S. Babayan, J. Park, G. Selwyn, and R. Hicks, *"The Atmospheric-Pressure Plasma Jet: A Review andComparison to Other Plasma Sources*,"IEEE Transactions on Plasma Science, Vol. 26, No. 6, pp. 1685–1694,1998.

[4] T. Yokoyama, M. Kogoma, T. Moriwaki, and S. Okazaki, "*The Mechanism of the Stabilisation of Glow Plasma at Atmospheric Pressure*," Journal of Physics D: Applied Physics, Vol. 23, No. 8, p. 1125,1990.

[5] P. Chu and X. Lu,"*Low Temperature Plasma Technology: Methods and Applications*." CRC Press, 2013.

[6] M. Benabbas, S. Sahli, A. Benhamouda, and S. Rebiai, "*Effects of the Electrical Excitation Signal Parameters on the Geometry of an Argon-Based Non-Thermal Atmospheric Pressure PlasmaJet,"* Nanoscale Research Letters,Vol.9, No.1,p.697,2014.

[7] Schutze, J. Jeong, S. Babayan, J. Park, G. Selwyn, and R. Hicks, "*The Atmospheric-Pressure Plasma Jet: A Review and Comparison to Other Plasma Sources*," IEEE Transactions on Plasma Science, Vol. 26, No. 6, pp. 1685–1694, 1998.

[8] Fridman and L. Kennedy, "Plasma Physics and Engineering ." CRC Press, 2004.

[9] Murakami T, Niemi K, Gans T, O'Connell D and Graham W G 2013 Chemical kinetics and reactive species in atmospheric pressure helium–oxygen plasmas with humid-air impurities Plasma Sources Sci. Technol. **22** 15003

[10] *Ghasemi M, Olszewski P, Bradley J W and Walsh J L 2013 Interaction of multiple plasma plumes in an atmospheric pressure plasma jet array J. Phys. D: Appl. Phys.* ***46*** *52001*

[11] Xiong R, Xiong Q, Nikiforov A Y, Vanraes P and Leys C 2012 Influence of helium mole fraction distribution on the properties of cold atmospheric pressure helium plasma jets J. Appl. Phys. 112 1–9

[12] D. Staack, B. Farouk, A. F. Gutsol, A. A. Fridman, "Spectroscopic studies and rotational and vibrational temperature measurements of atmospheric pressure normal glow plasma discharges in air", Plasma Sources Sci. Technol., vol. 15, pp. 818-827, 2006.

[13] S. Wang, V. S. Gathen, and H. F. Dobele, "Discharge comparison of nonequilibrium atmospheric pressure Ar/O_2 and He/O_2plasma jets," Appl. Phys. Lett. **83**, 3272–3274 (2003).

[14] Y. S. Seo, A.-A. H. Mohamed, K. C. Woo, H. W. Lee, J. K. Lee, and K. T. Kim, "Comparative studies of atmospheric pressure plasma characteristics between He and Ar working gases for sterilization," IEEE Trans. Plasma Sci. **38**, 2954–2962 (2010)