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Studying The Non-Thermal Characteristics Of Mixed Gases Plasma Jet

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Abstract:

This study will be presenting the construction process of a home-made non-thermal plasma jet. And discussing using a dielectric barrier discharge (DBD) atmospheric pressure plasma jet (APPJ) to create a non-thermal plasma using an alternating current (AC) power supply in order to provide 8 and 10KVp−p voltages with frequencies up to (21kHz) with mixed gases(He+O_2). The plasma jet system will be based on two-electrodes configuration, mainly based on double ring electrodes structure type. Thus, every configuration will be utilizing two Pyrex tubes which are 0.8mm wall thickness Pyrex tube and after that another Pyrex tube with 2mm wall thickness to notice the difference in the generation and the different characteristics.-

Keywords: Plasma, DBD, AC, mixed gases, electrodes, cold, atmospheric, the non-thermal, helium, s.l.m.,jet, APPJ,Helium gas, Oxygen gas,flow rate.

Introduction:

Plasma is a term that was used first time to describe an ionized gas in 1927 by Irving Langmuir who thought that the way of blood carrying its contents which are the red and white corpuscles with the way of an electrified fluid usually carries all the electrons and ions. Plasma physics and plasma based technology applications have made large progress in recent years. They usually play a very vital role in many of today's materials processes. These include: sputtering, etching, nitriding, biomedical applications, photolithography, among many others [1,2,3].

Plasma: The plasma describes many neutral substances consisting of ionized atoms and free electrons molecules that showed collective behavior due to the coulomb forces. Charged particles are not usually found in all media, still, they are classified as plasmas [4]. People always fascinate all the plasma appearances in nature, like the aurora borealis, sun and lightning. Tonks and Langmuir for indicating to the internal area, far from the boundaries, in lighting gas made by an electric discharge that happened in a tube, the ionized gas as a whole remaining electrically neutral. Another definition of plasma is the matter that is electrically conducting even when the weak coupling approximation doesn't even hold [5]. there are also "strongly coupled plasmas", which are the "plasma crystal" states…. The plasma term was used by Irving Langmuir. Which describes the electrons and positive ions generated by the electrical discharge [6]. Studying of plasma physics is included in all plasma physical properties. The plasma is the fourth state of substances and form (99) % of all universe materials [7]. The sterilization by plasma is used in1968 when Menashi founded the use of the radiofrequency field to remove and kill bacteria and spores [8].

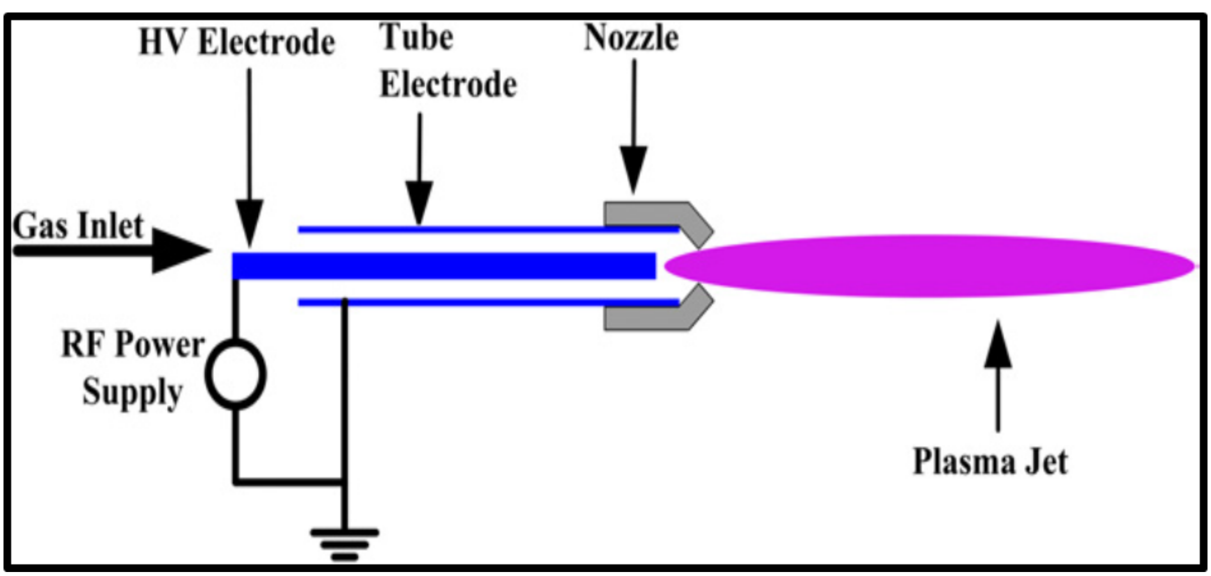
Atmospheric Pressure Plasma Jets:

Many industrial applications were used during the past two decades. Importance and development of the cold plasma technology depended on principal utilization of ANTP with its applications that are implicated in many fields including aerospace and aeronautics engineering and the environment engineering, textile technology, analytical chemistry and biomedical field. The cold plasma technology is considered energy saving, flexibility, environment-friendly and clear ecological advantages. Much other biological applications in the deactivation of bacteria, disinfectant of yeast like candida Albicans, and many dental applications like endodontic, cavity preparation, teeth whitening, also for wound healing, and recently for cancer treatment and others [9,10].

Dielectric free electrode (DFE) jet:

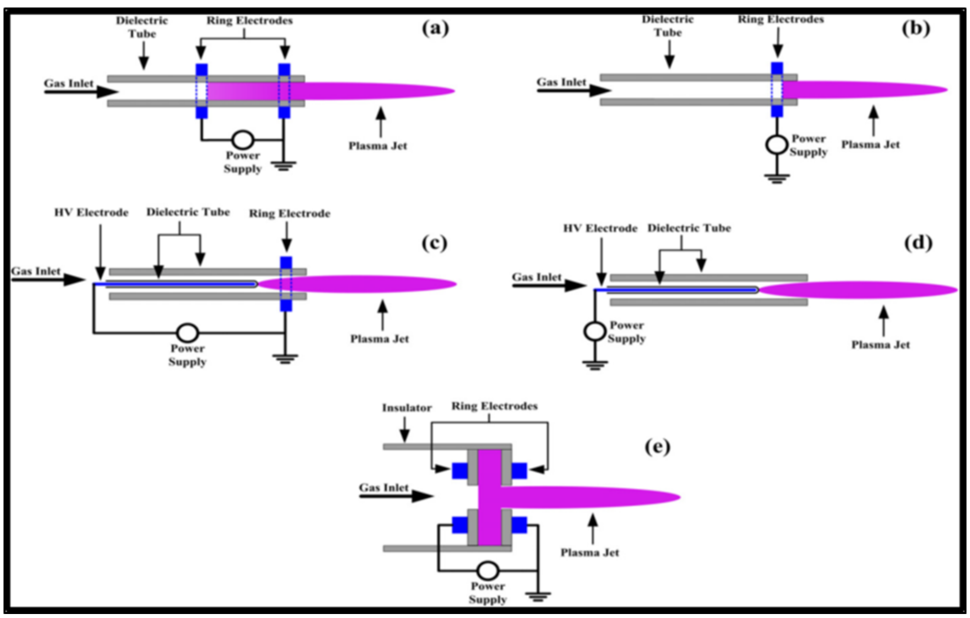
(DFE) jets is showed in figure (1), it operated by the power supply of the radio frequency (13.56) MHz. It formed from the external and internal electrode. The external electrode is tube contain on helium gas lie at the internal electrode with power supply. The (He) gas is mixed with other gases in the tube. The RF power was high (50- 500) W. temperature of the gas is much high (50-300) ^{o}C. while there is a very high electrical field in the discharge gap of DFE jet because the peak-applied voltage is only a few hundred.

Because of the RF power and temperature of plasma are high; DFE is outside the suitable range for biomedical applications and can be only used in the application of the material treatment which is not affected by high temperature [11].



Dielectric Barrier Discharge (DBD) jet:

The figures (a)–(e) showed many configurations. The figure (2) -(a), was presented by Teschke et, al. [63], the plasma jet made from the dielectric tube with (2) metal ring electrodes placed on the tube. When the working gas is flowingfrom the dielectric tube and the power supply is being turned on at high voltage, the cold plasma is produced in environment air. The plasma jet needs several watts as power. The temperature of gas nearly (25) °C. the gas velocity is usually less than (20 m $s^{-1)}$. Even though The plasma jet is totally homogeneous, but it hasa bullet like plasma volume and a propagation speed of more than (10 km s^{-1}). Usually, the electric field plays a vital role in the plasma bullet-like propagation. The gas has two advantages, the first is that plasma temperature will remain near to (25) ^{oC} because of low power density; also there is no arching on the sample [11].



Homemade DBD Plasma Jet System

It represents a homemade plasma system that was constructed for this study as composed of different parts as illustrated in figures (3) and (4)

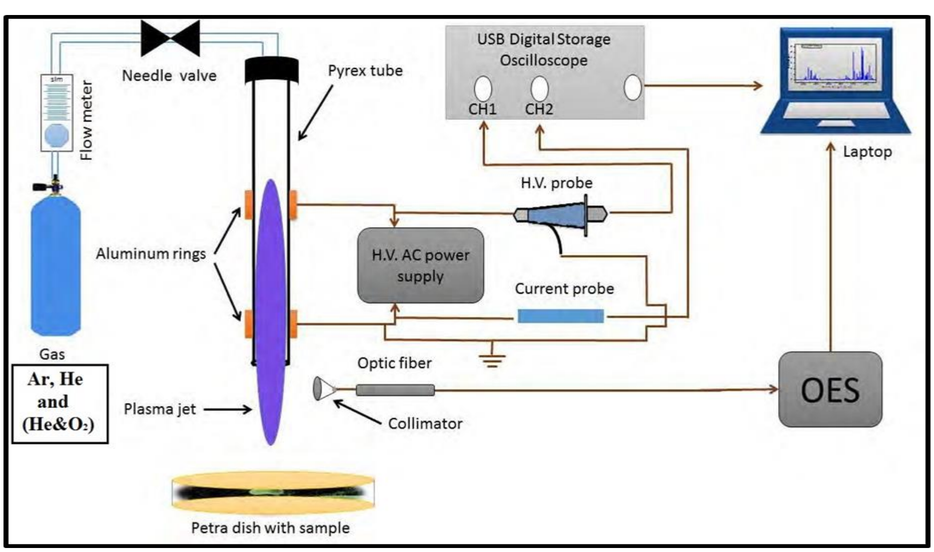


Figure (3): A schematic diagram double- ring electrodes (DBD) plasma jet system and plasma diagnostics setup.

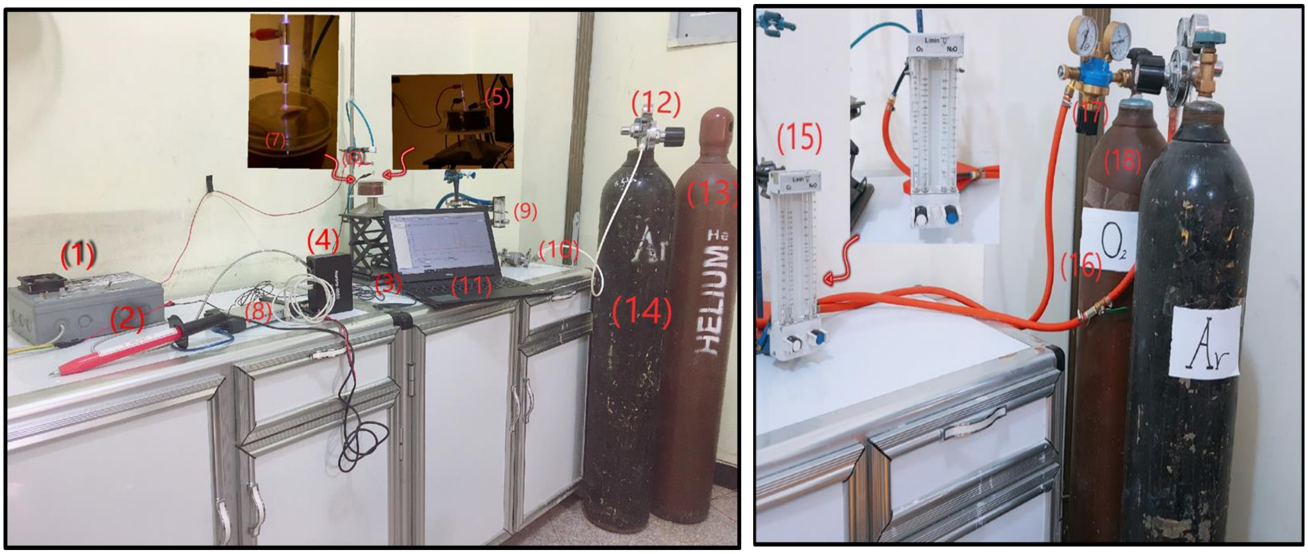


Figure (4): this figure shows a home-made DBD plasma jet system. (1) Home-made power supply, (2) HV probe, (3) Current probe (4), OES (5), Optical fiber with collimator, (6) Plasma plume, (8) PC USB Oscilloscope, (9 ,15) Flow meter, (10 ,16) Needle valve, (11) Laptop, (12, 17) Regulator, (13) Helium gas, (18) Oxygen gas.

2-Measurement of the Characteristics

the Plasma Plume Length measurements: the length of the plasma plume means the distance from the Pyrex tube's edgeto the tip of plasma plume or the it's the visible length of plasma plume in the air. It can be measured by using a metric ruler in different gas applied voltage and flow rate, it is one of the characteristics of the cold atmospheric plasma.

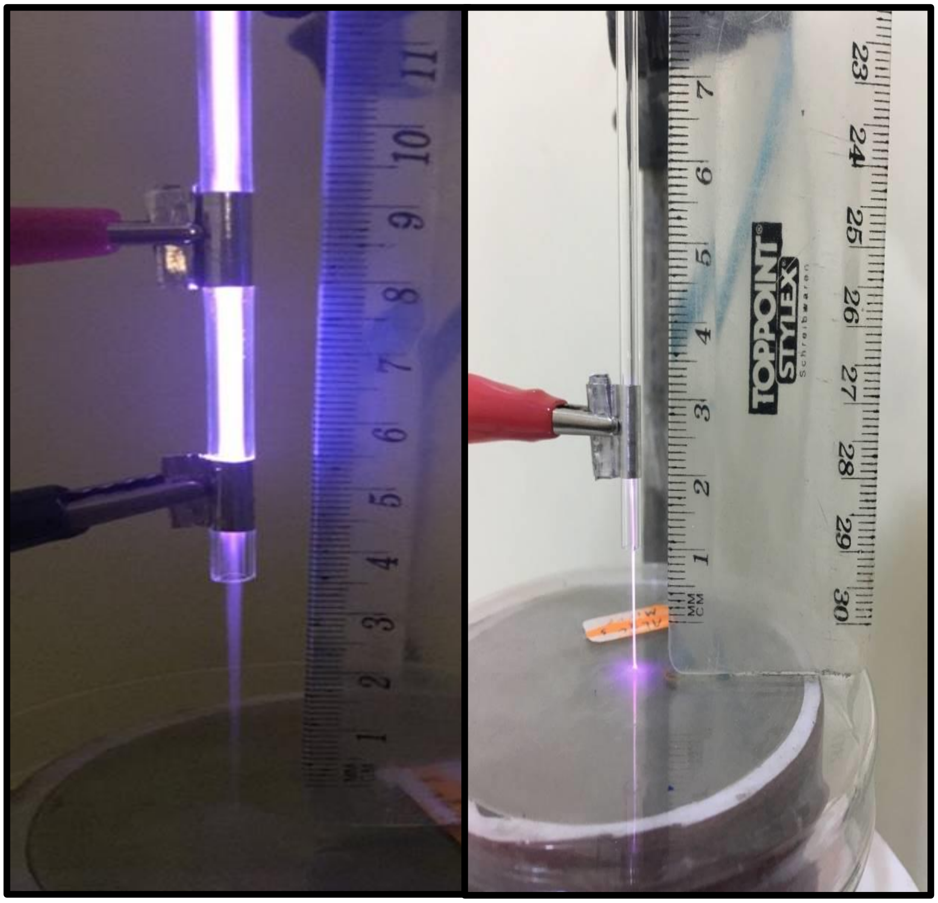


Figure (5): Length measurement of plasma plume.

This means that any increase in the gas applied voltage and gas flow rate will lead to increasing the length of the plasma plume, the voltage we will be using is (8) and (10) kVp-p while the frequency is almost 21HZ and mixed gases (He+O_2)we observed that the length of plasma plume was increasing every time we increase the flow rate of the working gas or even increasing the applied voltages as seen in the figures

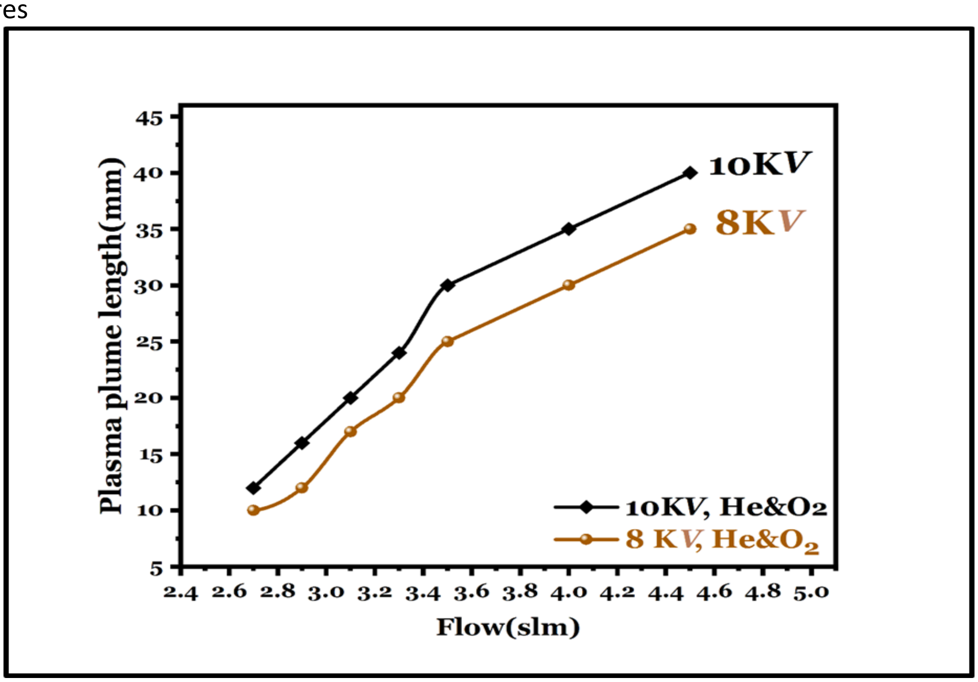
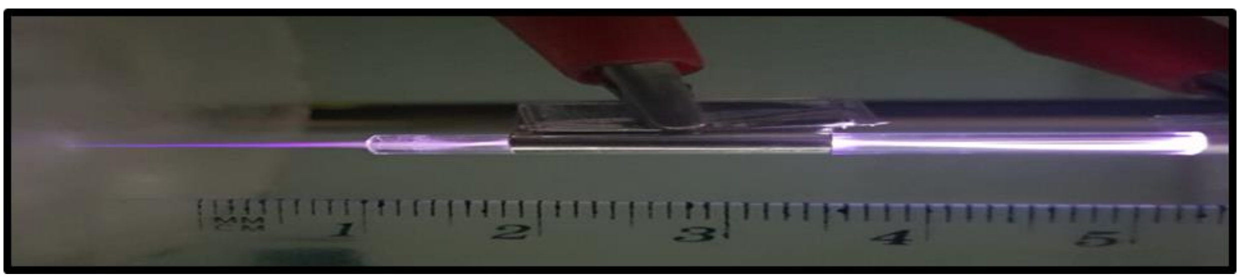


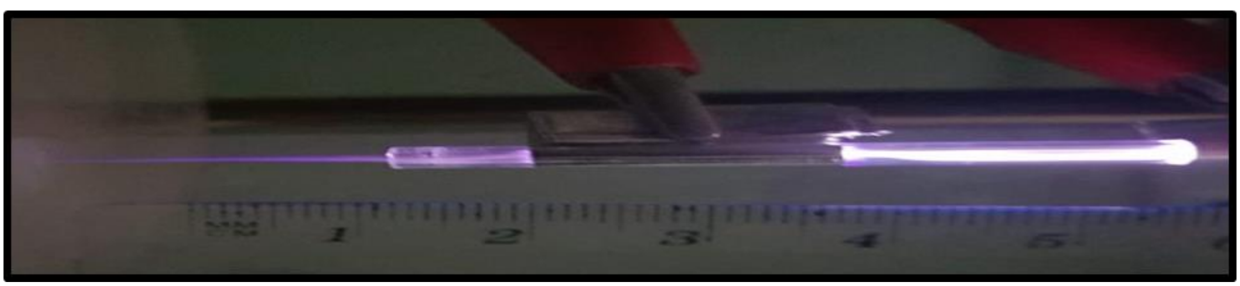
Figure (6): A schematic diagram of plasma plumes for different (He+O_2) mixed gases flow rates at 8 &10 KV and 21 kHz.

Table (1): A table show the relation between the plasma plume length in different (Helium+O_2) gases flow rates.

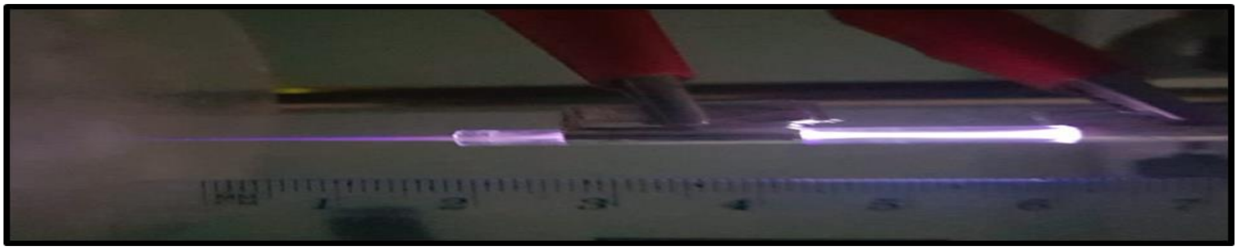
He&O_2					
8KV			10KV		
Flow(He) (slm)	Flow(O_2) (slm)	Plasma plume length(mm)	Flow(He) (slm)	Flow(O_2) (slm)	Plasma plume length(mm)
0.2	2.5	10	0.2	2.5	12
0.4	2.5	12	0.4	2.5	16
0.6	2.5	17	0.6	2.5	20
0.8	2.5	20	0.8	2.5	24
1	2.5	25	1	2.5	30
1.5	2.5	30	1.5	2.5	35
2	2.5	35	2	2.5	40



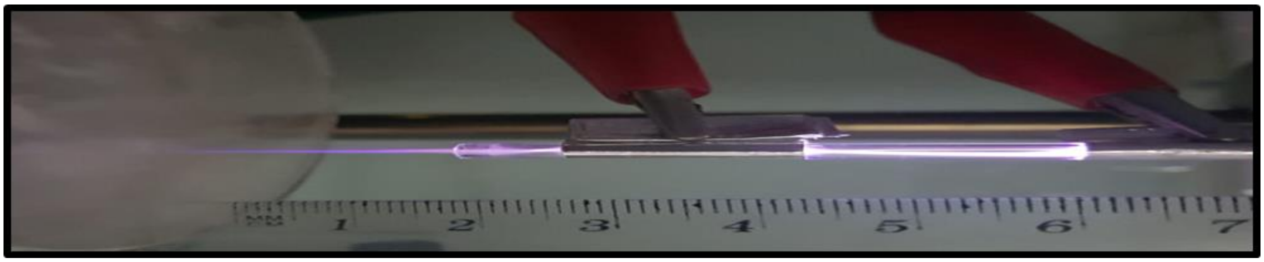
(0.2&2.5) s.l.m.



(0.4&2.5) s.l.m.

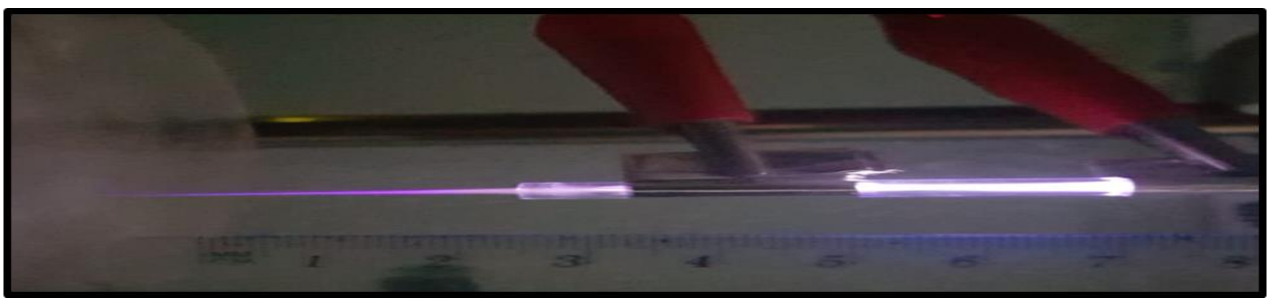


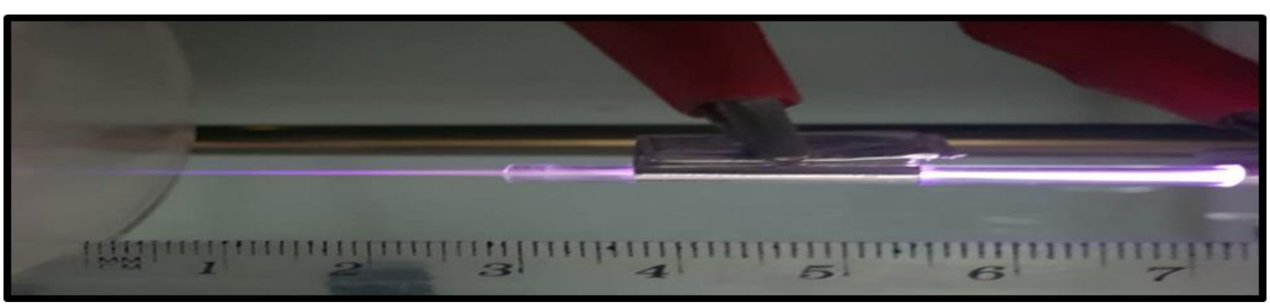
(0.6&2.5) s.l.m.



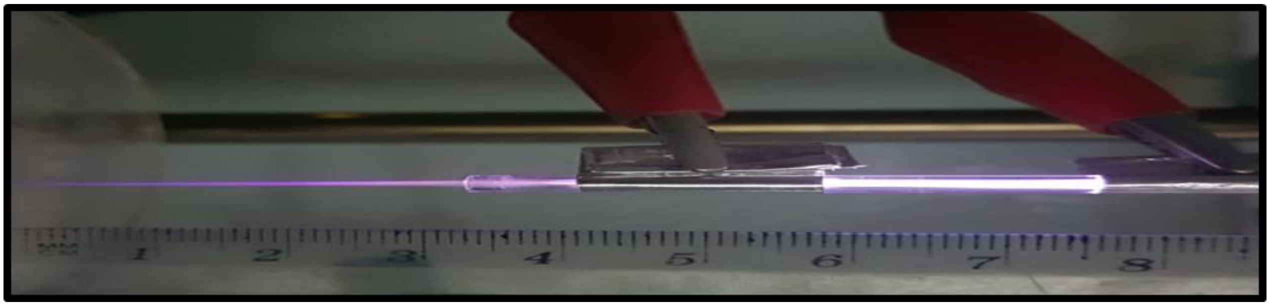
(0.8&2.5) s.l.m.

(1&2.5) s.l.m.



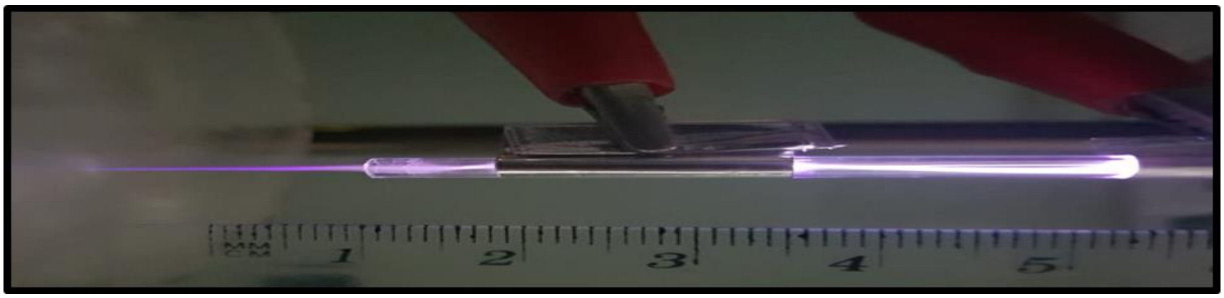


(1.5&2.5) s.l.m.

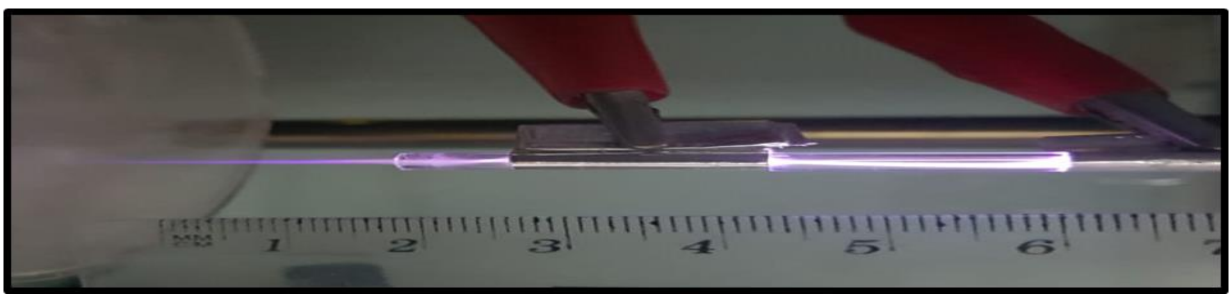


(2&2.5) s.l.m.

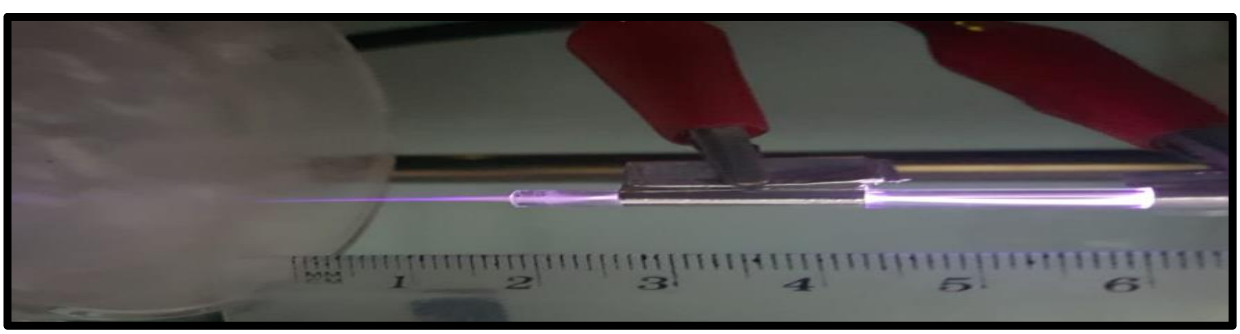
Figure (7): Photographs show plasma plumes for many(He+O_2) flow rates at 8 kV and 21 kHz.



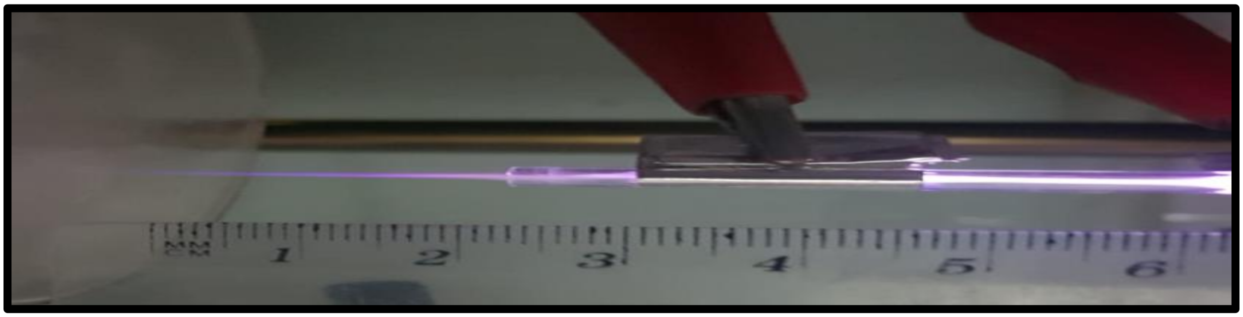
(0.2&2.5) s.l.m.



(0.4&2.5) s.l.m.

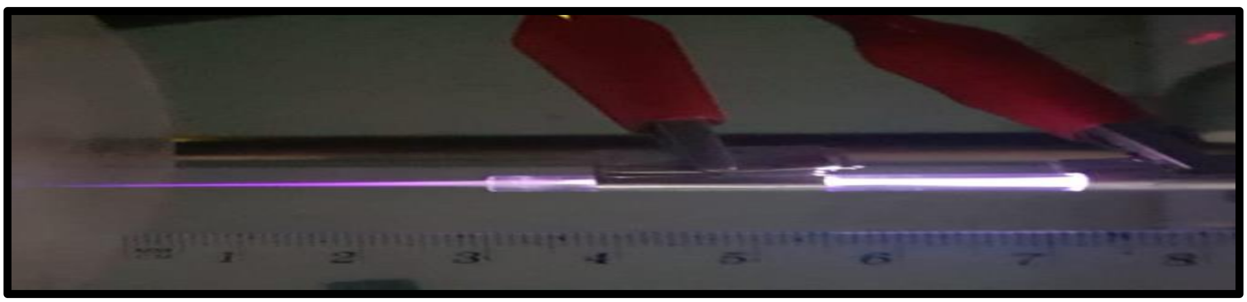


(0.6&2.5) s.l.m.

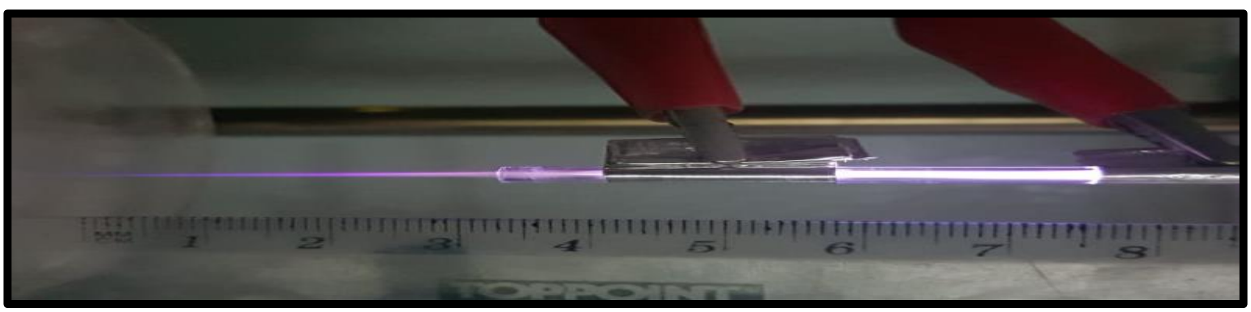


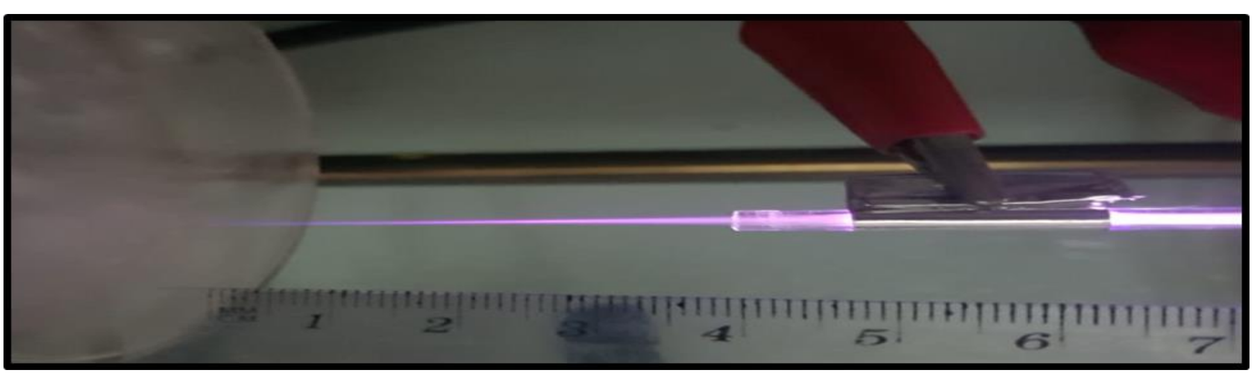
(0.8&2.5) s.l.m.

(1&2.5) s.l.m.



(1.5&2.5) s.l.m.





(2&2.5) s.l.m.

Figure (8): Photographs of plasma plumes for different (He+O_2) mixed gases flow rates at 10 KV and 21 kHz.

The length of the plasma jet column as a function of voltage:

The plasma jet usually seen inside and outside the tube column. As we notice in the figure (9). The plasma plume increased with increased applied voltage, the plasma jet will be pushed through the end of the tube. The length of the plasma jet was calculated by measuring the distance between the end of the tube column and the end of the plasma jet. The length of the plasma jet will increase with increasing applied voltage and reach maximum length at maximum voltage [12].

While in figure (9) it was noticed that the increased in the plume length is due to increased (1.5He+2.5O_2) gas flowrate and the increased applied voltage [13].

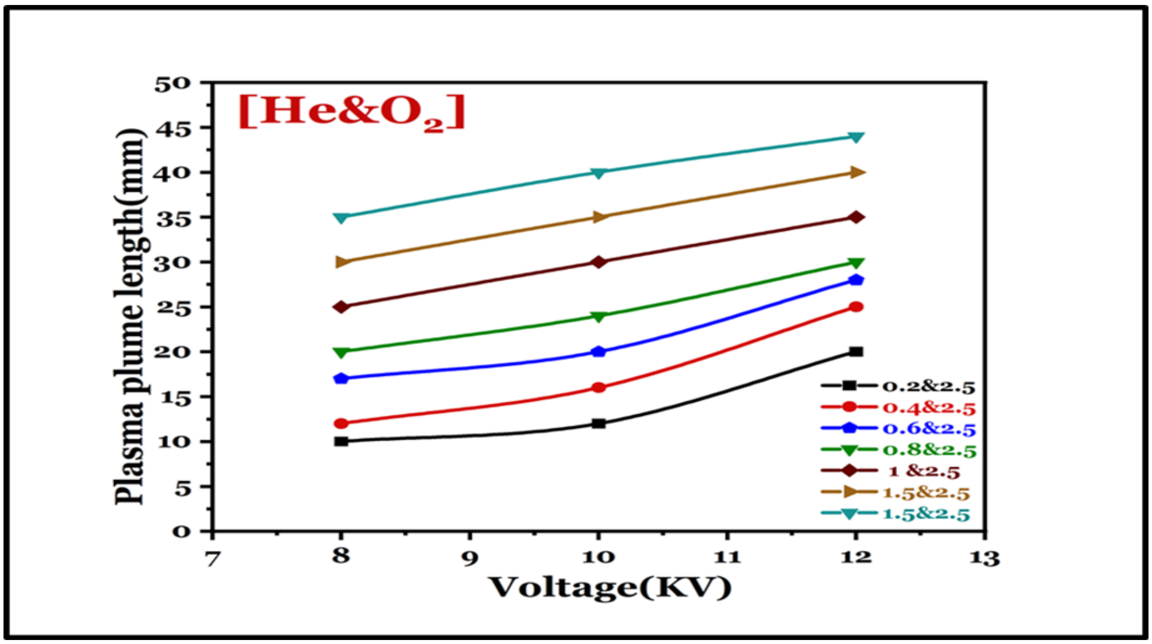


Figure (9): A schematic diagram of the relation between plasma plumes for different (He+O_2) gas flow rates and applied voltages at 21 kHz.

Temperature measurements of Plasma Jet:

the plasma jet temperature can be measured by utilizing a mercury thermometer by applying the heat sensitive end at different distances from the nozzle of the Pyrex tube and by using different gas flow rates, it was observed that the temperature of helium plasma was decreasing even more than the temperature of argon plasma with increasing plasma plume.

Besides, an increase in the gas flow rate will directly lead to a decrease in the helium plasma temperature with time until it will be fixed at (30sec-20min) and also by increasing the applied voltages the temperature will increase

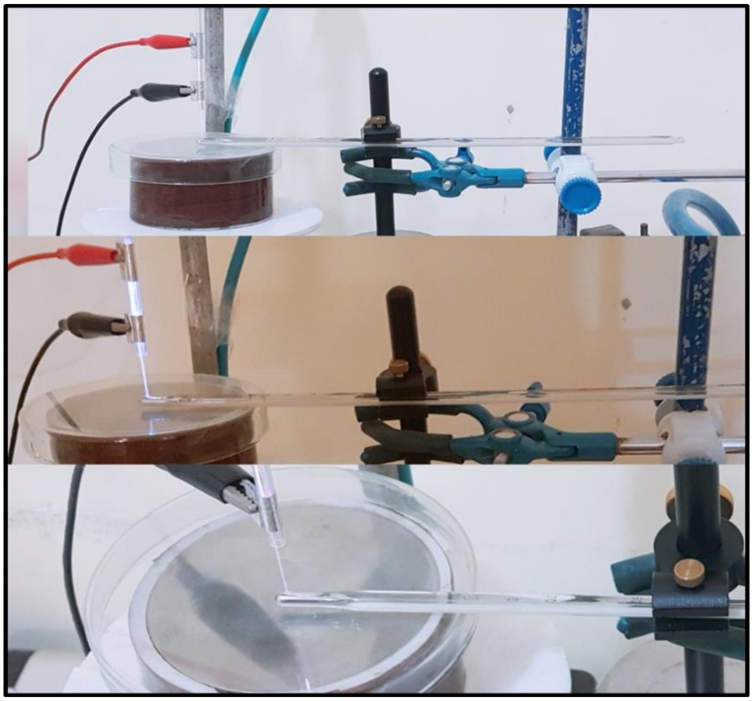


Figure (10): Temperature Measurement of plasma plume.

In this part, we will try to focus on measuring the plasma temperature in different plume length and different times and also for different gases like (helium and argon and mixed gases (1.5He+2.5O_2))

In fixed system conditions which are (21 kHz and 8 KV) the temperature of the room was (29) °C during measurements

Figures (11,12and13) shows the temperature of plasma as a function of time for different flow rates and different gases (helium, argon and mixed gases(1.5He+2.5O_2)). The plume length of plasma was (20) mm. as it was noticed that the highest temperature was in argon almost (43) °C at (2) min when the flow rate of gas was almost (1) slm.

The lowest temperature of plasma jet was while the lowest temperature reached (31) °C in (30) sec and the gas flow rate was (6) slm. While in helium plasma jet, the highest plasma jet temperature was (41) °C at two mins when the flow rate of gas was almost (1) slm, and the lowest plasma jet temperature was (28) °C at (30) seconds when the flow rate of gas is almost (6) slm. And for the mixed (He+O_2) the lowest temperature was (28) °C at (2slm He+2.5O_2) flow rate in (30) seconds while the highest temperature for mixed gases (37) °C (2slm He+2.5O_2) flow rate in (2) mins.

So the plasma jet temperature raised with rising time in argon more even than in helium gas and reduced with raised flow rate in helium plasma jet more even than in argon. The helium gas temperature decreased more than argon with raised in plume length. Gas flow rates, the helium gas temperature decreased more than argon with the increased gas flow rate.

The higher temperature is for the argon plasma jet in compared with the helium plasma jet which can be as a result of thermal conductivity effect. In helium gas, the thermal conductivity is ten times that of argon (thermal conductivities for helium and argon are (0.15 and 0.017) W/ (m K), respectively), which means a higher temperature of argon plasma jet The plasma temperature for helium ad argon stay fixed from (2) mins to (20) mins same mentioned by Laroussi et al [14.15].

The thermal conductivity can affect highest temperature for different gases such as helium and argon and also decreasing the distance from the tube end and the target cells can lead to rising plasma temperature which can also lead to bacterial inactivation but this should be done with caution so not to increasing the plasma temperature to the degree more than (44) °C that may cause cells damage [16].

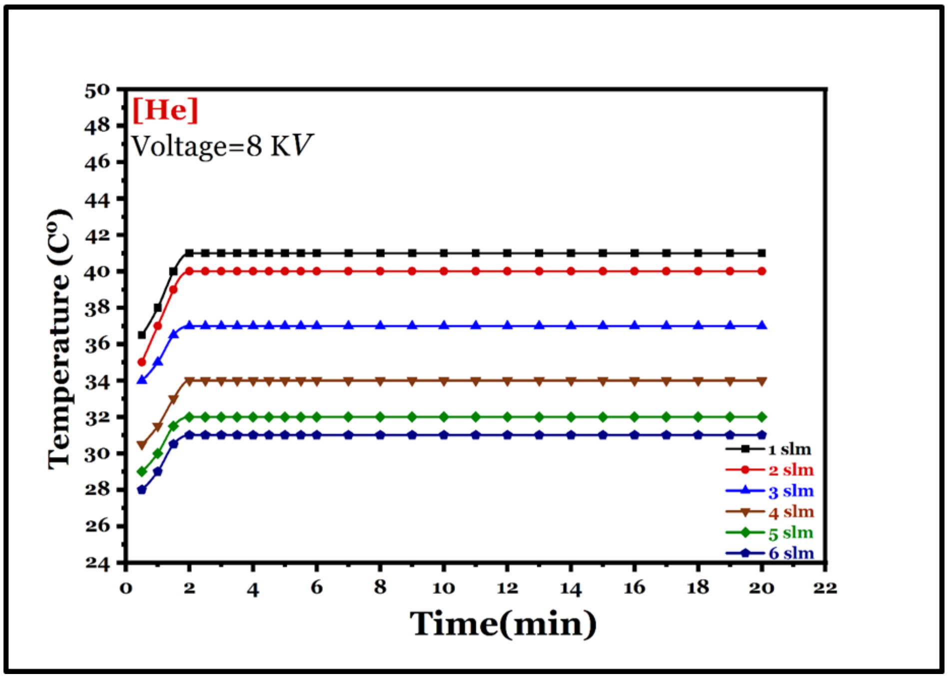


Figure (11): illustrates the helium non-thermal plasma jet as a function of the time for many various gases flow rates.

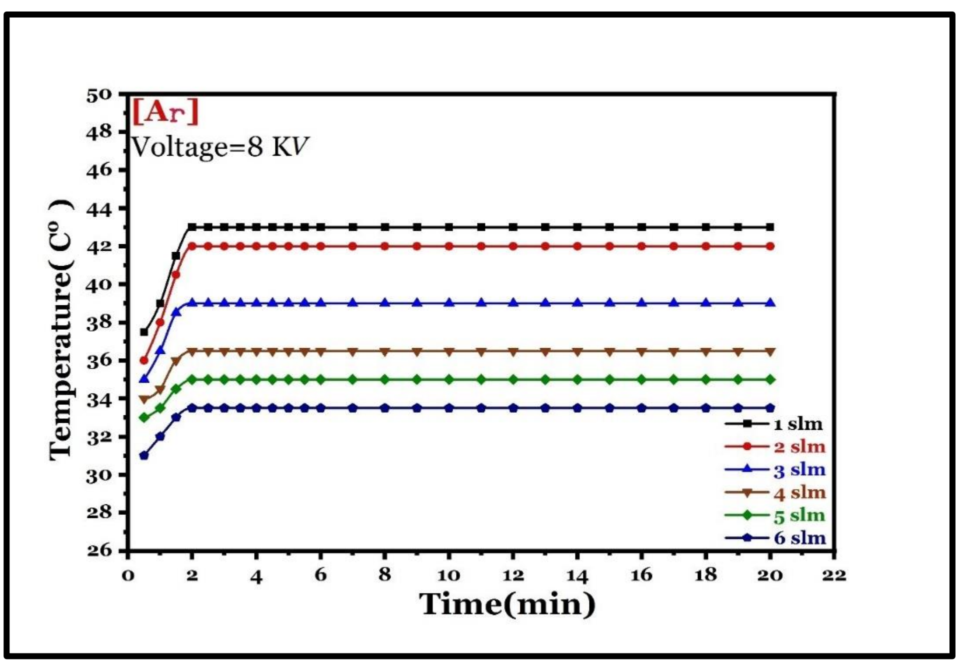


Figure (12): illustrates the argon non-thermal plasma jet as a function of the time for many various gases flow rates.

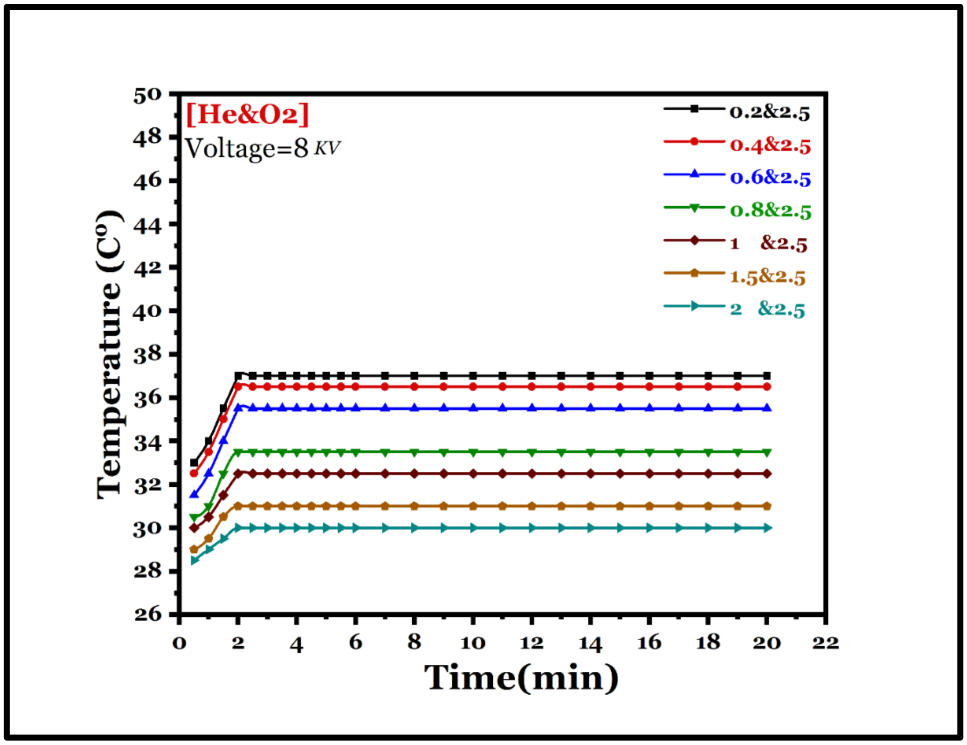


Figure (13): illustrates mixed gases (He+O_2) non-thermal plasma jet as a function of the time for many various gases flowr ates.

3. Discussion

Ahome-made non-thermal DBD plasma jet has been successfully built and we studied its characteristics. Any reduction in the wall thickness of the pyrex tube will have a direct effect on the plasma jet and also will decrease the plasma get temperature. The length of plasma plume is usually depending on the flow rate and the applied voltage type, 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 mixed gases(He+O_2)plasma jet will be decreased by any increase in the gas flow rate, while increased with higher voltage. The plasma jet temperature increases with increasing time in argon more than mixed gases(He+O_2) and helium and decreased with higher flow rate in mixed gases(He+O_2)and helium plasma jet more than in argon gas which has a high era flow rate of gas and applied voltage lead to increase the length of plasma plume and also the plasma plume width in helium increased.

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