DOI: http://dx.doi.org/10.21123/bsj.2018.15.1.0081

Effects of Gas Flow on Spectral Properties of Plasma Jet Induced by Microwave

Sabah N. Mazhir[1*] ***Nada A. Abdullah[2]*** ***Aws F. Rauuf [3]*** ***Alyaa H. Ali[4]***
Hazim I. al-Ahmed[5]

Received 11/12/2017
Accepted 11/2/2018

Abstract:

In this paper, a construction microwave induced plasma jet(MIPJ) system was used to produce a non-thermal plasma jet at atmospheric pressure, at standard frequency of 2.45 GHz and microwave power of 800 W. The working gas Argon (Ar) was supplied to flow through the torch with adjustable flow rate using flow meter regulator. The influence of the MIPJ parameters such as applied voltage and argon gas flow rate on macroscopic microwave plasma parameters were studied. The macroscopic parameters results show increasing of microwave plasma jet length with increasing of applied voltage, argon gas flow rate where the plasma jet length exceed 12 cm as maximum value. While the increasing of argon gas flow rate will cause increasing into the argon gas temperature, where argon gas temperature the exceed 350 °C as maximum value and study the effect of gas flow rate on the optical properties.

Keywords: Plasma parameters, Microwave plasma jet, Optical properties.

Introduction:

Plasma is commonly an ionized gas. It is combining of charge particles (electron, ion and molecules). The term ionized return to the existence of one or more free electron. Which are not required to an atom or molecules (1,2). It have free charge particles where the positive and negative charge approximately stasis each other at the level of the macroscopic. It resulted when the elements are heated to temperature more than the thermal energies and above binding energies for special state of matter. When the environment temperature increasing the division of atoms can be broken down into negative charge electron and positive charge ion. These particles will contact with each other through the electromagnetic(3,4).

Microwave discharges produce non-equilibrium plasma since the electrons can respond to the oscillations of the electric field whereas the ions are not able to respond due to their large mass. So most of the microwave energy goes preferentially to the electrons, and then produce plasma far from thermodynamic equilibrium(5). Glow discharges generated by microwave power supplies through coupling of electromagnetic radiation of frequency ranging from 300 MHz to 10 GHz are named as microwave induced plasmas. Power supplies operating at a frequency of 2.45 GHz. This kind of plasma may be considered in local thermodynamic equilibrium (LTE) and non-local thermodynamic equilibrium (non-LTE) (6, 7, 8). Atmospheric microwave induced plasma (MIP) sources are cheap thanks to without needing to vacuum system, strong to operate for a long time, and safe to be crazed by living tissue such as a human body directly (9,10). One of the most commonly used methods to diagnose plasma is optical emission spectroscopy. The plasma spectral diagnostic methods are based on measuring the intensity of the spectral lines of emission and absorption and the continuous spectrum, half widths and shifts of spectral lines. Optical emission from a plasma occurs primarily through the electron impact excitation of atoms or molecules to an excited state, followed by a relaxation to a lower energy state releasing a photon containing an energy equal to the difference between these two energy states. (11, 12) In comparison with other numerous diagnostic techniques that recognizes other transient processes/ occurrences, the optical emission spectroscopy (OES) has many advantages, such as obtaining. information of the constituted elements, in addition of studying plasma expansion dynamics(13, 14, 15, 16).

[1, 2, 4] Department of physics, College of Science for Women, University of Baghdad, Baghdad, Iraq.
[3]Ministry of Science and Technology, Materials Researches Directorate, Baghdad, Iraq
[5]Biotechnology Research center, Al-Nahrain University, Iraq.
[*]Corresponding author: dr_sabah68@yahoo.com.

Experimental setup

The diagram of the setup used for experimental investigations of microwave plasma sources is shown in the Fig (1). Its essential components are: Microwave generator (magnetron), Tapered rectangular waveguide, Plasma discharge tube, Ignition system, Gas supply and flow controller.

The spectral detection was performed with a spectrometer (THORLABS CCS200, wavelength range 200−1000nm, Spectral Resolution <0.5nm FWHM @ 633nm) with resolution 4 px/nm was used to diagnose plasma jet parameters such as electron temperature T_e and electron density n_e. The S200 is of great sensitivity, receives light energy emitted via optical fiber and spreads it through a fixed grating across the detector. The gas temperature is measured by using infrared thermometer (fluke 62 max, china).

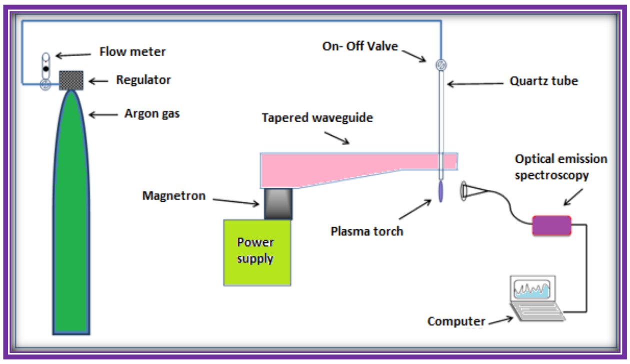


Figure 1. a photograph of the microwaves induced plasma jet system

Results and Discussion:

1- Plasma Torch Length.

The increasing in the length of plasma flame that created in MIPJ system was measured as a function of microwave power and gas flow rate effects, where the plasma flame length does not exceed 12 cm out of orifice torch due to the high collision frequency at atmospheric pressure, it is not easy to generate a long non-equilibrium plasma plume at atmospheric pressure.

With increasing the microwave power at a fixed argon flow rate, the length of the plasma flame increased. Fig. (2) and (3) represent the increasing on the flame length with increasing of applied voltage. From Fig. (3) which shows the relation between the voltage and the plasma torch length at a different gas flow rate before the microwave (0V) and at microwaves voltage range from 150V to 220V. The plasma torch length increases gradually in linear relation with the increase of the applied voltage, this is true for all gas flow rate. For 1 l/min, the plasma torch starts at a value of 4 before the microwave (0V), the max value of plasma is 9.3 at 220. For 2 l/min, the plasma torch was 5.2 at 0v and the max was 9.5 at 220v. For 3 l/min, the plasma torch was 6.3 at 0v and the max was 10.3 at 220V. For 4 l/min, the plasma torch was 7 at 0v and the max was 11.2 at 220v. Finally, at 5 l/min gas flow rate, the plasma torch was 7.8 at 0v and the max was 12 at 220V. The result demonstrates that at a constant applied voltage, the plasma torch length increase as gas flow rate increases.

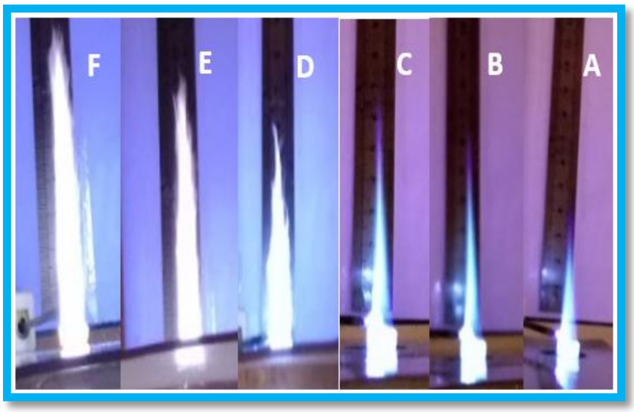


Figure 2. Photography for the flame length of plasma A) Applied voltage=0 V and gas flow=2 l/min, B) Applied voltage=160 V and gas flow=1 l/min, C) Applied voltage=170 V and gas flow=2 l/min, D) Applied voltage=180 V and gas flow=3 l/min, E) Applied voltage=190 V and gas flow=4 l/min, F) Applied voltage=210 V and gas flow=5 l/min at 10 mm diameter tube

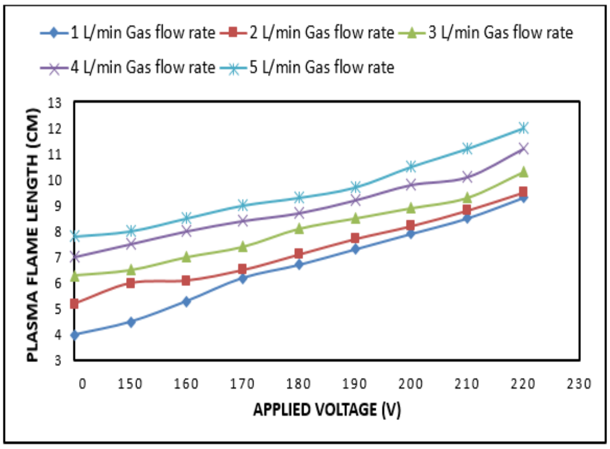


Figure 3. Plasma jet length versus applied voltages at different gas flow rates

2- Working Gas Temperature

Five levels of argon flow rates were used to study the behavior of gas temperature (T_g) as a function with applied voltage of plasma jet. This results of T_g reached to 350 $^{\circ}$C, so it`s useful for many biological applications.

The temperature of gas flow through microwave system has been studied as a function of the voltage at a different gas flow rate which is shown in figure(4). Before the microwave (0V) and when the voltage increased from 150V to 160V the temperature at all gas flow rate remains constant at an average value of 32^0C. When the voltage increased from 160V to 190V, the temperature increased from 34.6°C to about 180°C for all gas flows, but when the voltage increased from 190V to 210V, the temperature remains almost constant at average value 199.74^0C for gas flow range from 1L/min to 4 L/min. When gas flow increased to 5 L/min the temperature increase to 336^0C at 200V and increase slightly to 350^0C at 220V. As for other gas flow rates, the temperature at 4L/min increase to 290^0C at 220V. At 3L/min curve the temperature increased to 240^0C at 220V. For 1L/min and 2L/min, the temperature at 220V was 200^0C and 240^0C.

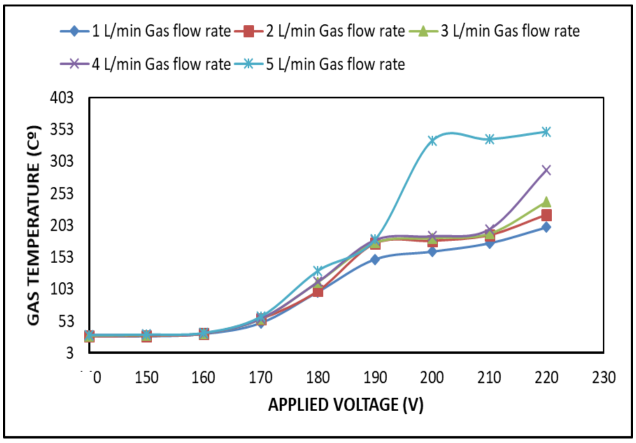
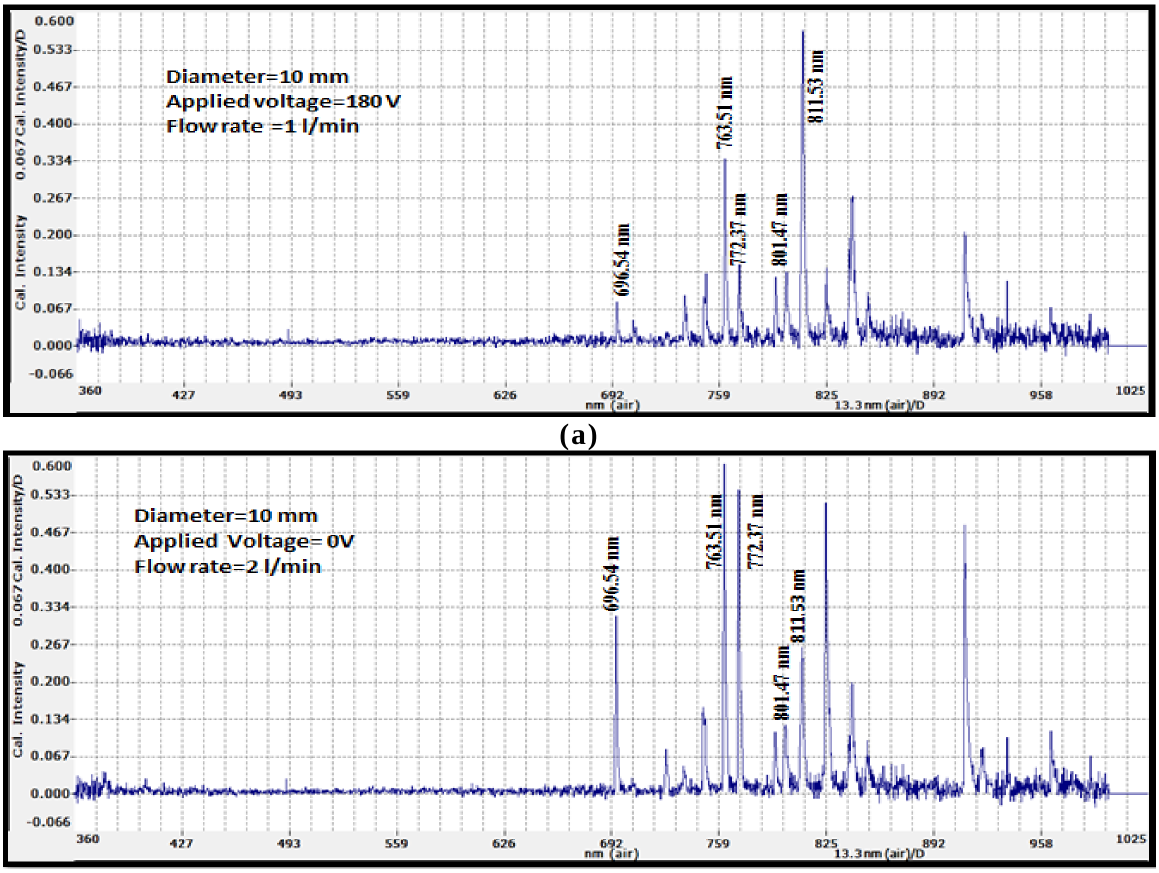


Figure 4. Effect of gas flow rate on the relationship between gas temperature and applied voltage

3-Characteristic of plasma spectra

OES is used to record argon plasma spectra by observing the electronic excited species and their intensities in the discharges that generated by argon MIPJ. A 72argon spectra obtained from these plasmas represent applied voltages repeated with three rates of gas flow values for each of three diameters of discharge tube. Fig. (5) shows a two selected emissions spectra of the atmospheric MIPJ have different flow rates of 1 and 2 $\ell min^{-1}$with different in applied voltage of 0V (before microwave plasma) and 180 V of the spectra represents a sample of 72 spectra that recorded in this work, all emission spectra of argon MIPJ have same peaks positions but different intensities.

Fig. (6) Illustrates the Intensity curve is plotted as a function of applied voltage to the microwave system and the curves were drawn for standard wave length (763.51, 772.37, 801.47 and 811.53) nm at a different gas flow rate. The zero volt (0V) in the chart means the measurement of the intensity was taken without the microwave. As shown there is no difference between the intensity at 0V (without the microwave) and the one with microwave at 150V for all standard wave length at 1L/min gas flow rate. For 1 L/min flow rate the curve of all standard wave length has the same behavior. It starts from applied voltage 150 at an intensity less than 0.1 and when the voltage increases the intensity also increases rapidly until it peaked, then drop quickly and tend to saturate at 180 V with intensity value less than 0.5.This value remains constant for voltage higher than 180. The 811.53nm curve has the highest intensity of 4.5 at 170 V flowed by 801.47 nm curve with the intensity of 4 at 170. The other two curves 722.37nm and 763.51nm both behave the same and have the same peak intensity at 170V. When the gas flow rate increased to 2 L/min as shown in Fig.(7) all intensity at any applied voltage has less value than other gas flow rates (1, 3, 4 and 5) L/min. The intensity at 0V and 150V remains the same for standard wavelengths (801.47nm and 811.53nm), but it decreases for 763.51nm and 772.37nm. The lowest intensity value was shown in both standard wavelength curves (801.47 and 772.37) nm, the value was 0.041 at 170V. The highest intensity was founded in an 811.53nm curve, the value was 0.8 at 160 V. All the standard wavelength curve behave like wave function; they start at 150 peaked at 160v and then fall to 170V, at 180 they rise again then the intensity tends to decrease slowly until it reaches constant intensity at 210v and remains constant at a higher voltage. At a voltage range from 170 to 220, both standard curves (801.48nm and 772.37nm) have the same intensity value. At 3L/min gas flow rate as shown in Fig. (8). For all standard wavelength curves, there is no intensity difference between the 0V and 150V for all standard wavelength. The value of intensity was less than 0.1 at 150v, then the intensity increases gradually with voltage until it reaches 160V that was the intensity at the max value and for higher voltage than 160, the intensity value remains constant. The max intensity value was 4.346 at 160 V for 811.53nm curve flowed by the 801.47nm curve with the intensity of 4.05 at 160V. The least intensity value was for both standard wavelength curves 763.51nm and 772.37nm which both have nearly the same intensity value for all applied voltages. Fig. (9) shows the relation between applied voltage and intensity for gas flow rate value 4L/min. The intensity remains the same before the microwave (0V) and with microwave at 150V. The behavior of all curves at any standard wavelength was similar to 3L/min curves. All curves start at an intensity less than 0.5 as shown at 150v. The intensity curves with standard wavelength (763.51 and 811.53) nm increase gradually from 150v to 160v and for higher voltage the intensity value for both curves remains constant. For 763.51 nm curve, the max value of intensity was 3.271 while for 811.53 nm curve the max intensity value was 4.317. The other two standard curves (772.37 and 801.47) nm their intensity start from 150V increase gradually until it reaches 170V and their value remains constant for higher voltage. For the 772.37nm curve, the max intensity was 3.5 while for 801.47 nm curve the max intensity value was 4.061. In Fig.(10), The intensity was measured at 5L/min for standard wavelengths (763.51, 772.37, 801.47 and 811.53nm). The same intensity was noticed before the microwaves (0V) and with microwave at 150V. All wave length curves starts at an intensity less than 0.5 at 150v. A voltage range from 150v to 160v the intensity increases gradually until it reaches its max value at 160v. The max intensity of 811.53 nm curve was 4.351 at 160V and for higher voltage, the intensity remains constant. For 763.51nm, the max value at 160v was 3.341 and this value stays constant for the rest of higher applied voltage. Both the (801.47nm and 772.37nm) have a similar response for voltage range from 170v to 220v. The max intensity for 801.47nm and 772.37nm was 2.124 and 3.124, respectively.



(a)

(b)

Figure 5. A two emission spectra of atmospheric Argon MIPJ.
(a)V=180, flowvate=1 L/min, (b)V=0, flowvate=2 L/min

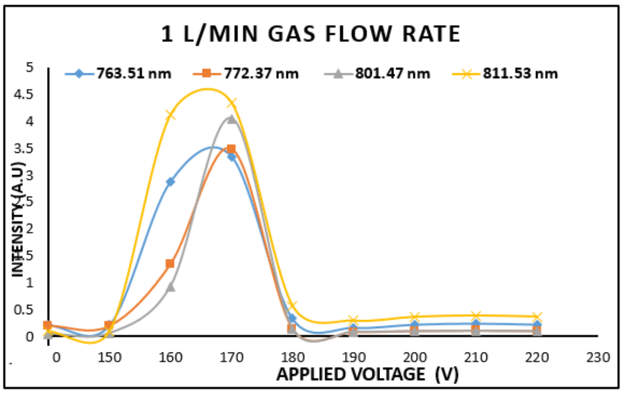


Figure 6. Effect gas flow rate on relationship between the intensity and applied voltage at different wavelength

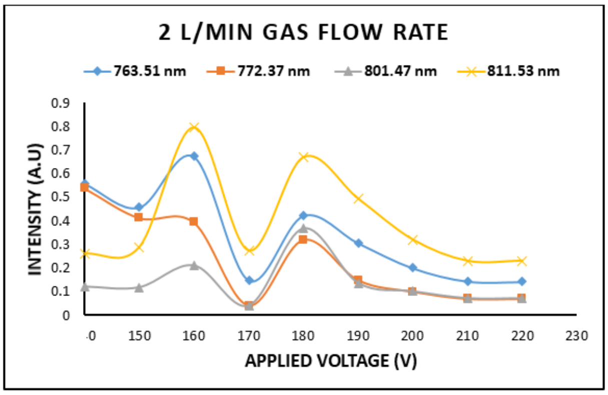


Figure 7. Effect gas flow rate on relationship between the intensity and applied voltage at different wavelength.

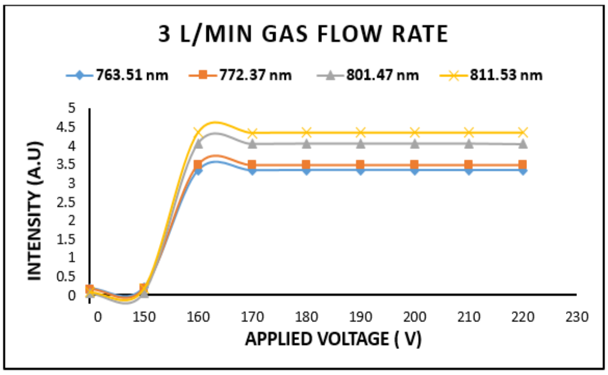


Figure 8. Effect gas flow rate on relationship between the intensity and applied voltage at different wavelength.

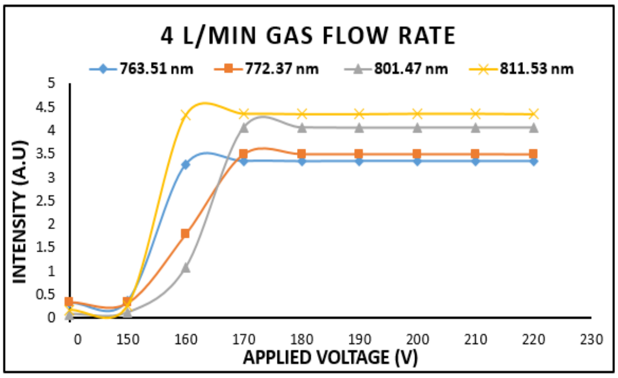


Figure 9. Effect gas flow rate on relationship between the intensity and applied voltage at different wavelength.

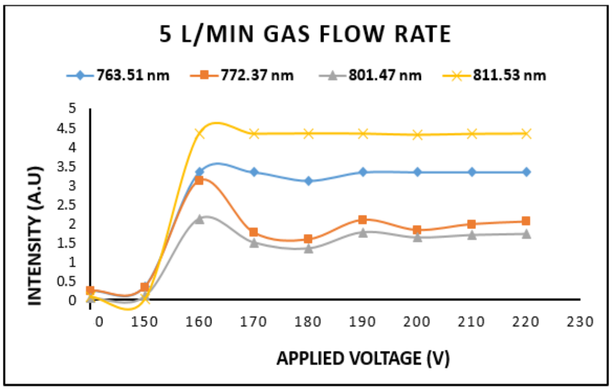


Figure 10. Effect gas flow rate on relationship between the intensity and applied voltage at different wavelength.

Conclusions:

The MIPJ system at atmospheric pressure was successfully constructed in the laboratory by using a domestic magnetron as a microwave source with simple and low cost equipment. This paper evaluated the development which has been made experimentally on plasma parameters Induced by Microwave. This was achieved by utilizing OES to determine plasma physical parameters. The effect of gas flow rate, and applied voltage were studied on the macroscopic characteristics (such as the plasma jet length, plasma jet volume and working gas temperature).

It is found that the increasing of argon gas flow rate, applied voltage and are causing increased in the length and volume of the plasma jet. On the other hand, the behavior of gas temperature shows decreasing with increasing in gas flow rates.

Plasma composition can be detected by OES by the careful monitoring of electronically the stimulated species and their intensities in the discharges produced by Ar plasma torch. Within the range (200 -1000) nm and utilizing a spectrometer (S2000), the spectra were detected. The S2000 is of great sensitivity, receives light energy emitted via optical fiber and spreads it through a fixed grating across the detector. The emission spectrum that covering the region of spectral (200 – 1000) nm that.

References:

1. Szabo D, Schlabach S. Microwave Plasma Synthesis of Materials—From Physics and Chemistry to Nanoparticles: A Materials Scientist’s Viewpoint. Inorganics. 2014; 2(3) :468–507.
2. Mazhir S, Ali AH, Abdalameer NK, Hadi FW. Studying the effect of Cold Plasma on the Blood Using Digital Image Processing and Images Texture analysis. International conference on Signal Processing, Communication, Power and Embedded System (SCOPES), IEEE Xplore Digital Library. 2016; 904-914.
3. Yahya KA, Mazher SN, Hafidh Z A. Study of Density Distribution in Entrained Plasma, Um-Salama Science Journal. 2007; 4(2): 305-309.
4. Mazhir SN, Hadi FW, Mazher AN. Alobaidy LH. Texture Analysis of smear of Leukemia Blood Cells after Exposing to Cold Plasma. Baghdad Science Journal. 2017; 14(2): 403-410.
5. Eliasson B, Kogelschatz UK. Nonequilibrium Volume Plasma Processing, IEEE Transactions on Plasma Science.1991; 19(6): 1063 – 1077.
6. Bogaerts A, Gijbels R, Effect of small amounts of hydrogen added to argon glow discharges: Hybrid Monte Carlo–fluid model. *Physical Review E*. 2002; 65 (5): 056402.
7. Zhan RJ, Wen X, Zhu X, Zhao A. Adjustment of electron temperature in ECR microwave plasma, Vacuum. 2003; 70(4): 499-503.
8. Fantz U. Basics of plasma spectroscopy, Plasma Sources Science and Technology. 2006; 15 (4): S137.
9. Iza F, Kim GJ, Lee SM, Lee JK. Microplasmas: Sources, Particle Kinetics, and Biomedical Applications**,** Plasma Processes and Polymers. 2008; 5(4): 322 -344.
10. Min UL, Lee JK, Gunsu SY. 2017. Generation of energetic electrons in pulsed microwave plasmas, Plasma Processes and Polymers. 2017; 14, 11.
11. Ebdon L, Evans EH, Fisher AS, Hill SJ. An Introduction to Analytical Atomic Spectrometry, John Wiley & Sons Ltd, England.1998.
12. Wasfi AS, Humud HR, Ismael ME. Spectroscopic Measurements of The Electron Temperature in Low

Pressure Microwave 2.45 GHz Argon Plasma, Iraqi Journal of Physics. 2015; 13 (27): 14-24.
13. Mazhir SN. Spectroscopic Study of (TiO2)1-x(CuO)x Plasma Generated by Nd: YAG Laser, ARPN Journal of Engineering and Applied Sciences. 2018; 13(3):864-869.
14. Abrar M, Khan AW, Naseer AS, Gilani AR, Zakaullah M. Effect of helium mixing on excitation temperature and nitrogen dissociation in inductively coupled plasma, Current Applied Physics. 2013;13: 969–974.
15. Hassouba M, Dawood NA. Comparative Spectroscopic Study on Emission Characteristics of DC and RF Discharges Plasma using Different Gases, Life Science Journal, 2014;11(9): 656-666.
16. Adim KA, Detection of laser-produced tin plasma emission lines in atmospheric environment by optical emission spectroscopy technique, Photonic Sensors. 2017; 7:6–7.

تأثير معدل تدفق الغاز على الخصائص الطيفية للبلازما المنتجة بواسطة المايكرويف

صباح نوري مزهر[1] **ندى عادل عبدالله[2]** **اوس فيصل رؤوف[3]** **علياء حسين علي[4]**
حازم اسماعيل الاحمد[5]

[4,2,1] قسم الفيزياء، كلية العلوم للبنات، جامعة بغداد، العراق.
[3] مركز بحوث المواد، وزارة العلوم والتكنولوجيا، بغداد، العراق.
[5] مركز التقنيات الاحيائية، جامعة النهرين، بغداد، العراق.

الخلاصة:

تم في هذا البحث بناء منظومة لتوليد البلازما غير الحرارية بواسطة المايكرويف عند الضغط الجوي وعند تردد 2.45 GHz وقوة للمايكرويف 800 w، اذ تم استخدام غاز الاركون لتوليد الشعلة بواسطة منظم الفلوميتر. كما تم دراسة تأثير الفولتية المطبقة ومعدل تدفق غاز الاركون على معلمات البلازما المنتجة. اظهرت النتائج زيادة طول شعلة البلازما عند 12 سم كأقصى حد. كما ان زيادة معدل التدفق للغاز يسبب زيادة في درجة حرارة غاز الاركون حيث تتجاوز درجة حرارته 350^oC . وباستخدام جهاز المطياف تم دراسة تأثير تدفق الغاز على الخصائص الطيفية للبلازما المتولدة.

الكلمات المفتاحية: معلمات البلازما، البلازما المنتجة بواسطه المايكرويف، الخصائص الطيفية.