The Effect of Magnetic Field on Helium Plasma Characteristics of Discharge Tube

Mahdya A. Yeser **Adel H. Omran** **Nibras F. Ali** **Einas R. Wadaa**

Adilh.alkhayat@uokufa.edu.iq nibrasf.alshammari@uokufa.edu.iq Eynas.merza@gmail.com

University of Kufa/College of Science/Physics Department

Abstract:

The effect of discharge voltage of a discharge tube were investigated.The discharge voltage (700,800,900,1000,1100,1200) volt were applied under pressure of helium gas was (7Pa) and the inter electrode distance was (130mm). The measurements were achieved without and with parallel magnetic field of (25 mT). The electron temperature calculated from $I_d - V_d$ characteristics curves of double Langmuir probe. Results of electron temperature indicated that the behavior of electron temperature decreased with increasing the discharge voltage with and without the magnetic field.But their values at (B=0) was smaller than the corresponding values at (B=25 mT).

Keywords: Glow discharge, Langmuir probes, Plasma diagnoistics.

تأثير المجال المغناطيسي على خواص بلازما غاز الهيليوم في إنبوبة التفريغ الكهربائي

مهدية أحمد يسر **عادل حبيب عمران** **نبراس فاضل علي** **إيناس رياض وداعه**

جامعة الكوفة/كلية العلوم/قسم الفيزياء

الخلاصة:

أنجز في هذا البحث دراسة تأثير فولتية التفريغ للفولتياتV (٧٠٠,٨٠٠,٩٠٠,١٠٠٠,١١٠٠,١٢٠٠) تحت ضغط غاز الهيليوم (٧ Pa) و المسافة بين القطبين الكاثود والأنود (١٣٠ mm). القياسات أنجزت بعدم وجود و بوجود مجال مغناطيسي مواز ذو الشدة (٢٥ mT). حسبت درجة حرارة الألكترون من منحني الخصائص لمجس لانكمور الثنائي. وقد وجد أن درجة حرارة الألكترون تقل بزيادة فولتية التفريغ في حالتي وجود و عدم وجود المجال المغناطيسي الموازي. لكن قيمها بعدم وجود المجال هي أصغر من قيمها بوجود المجال الموازي I_d-V_d.

الكلمات المفتاحية: التفريغ التوهجي، مجسات لانكمور، تشخيص البلازما.

1. Introduction

The development of a potential difference between two electrodes immersed in a low pressure inert gas environment results in an electrical discharge.Under certain conditions of gas pressure,current and voltage, a brilliant discharge is established. Close observation of this discharge reveals the existence of various regions[1].

Glow discharge are used in various applications such as deposition of thin films, etching and modification of surfaces in semiconductor industry and materials technology [2].

Langmuir probes are commonly used diagnostics in low-pressure plasma discharge <1 torr [3]. Of all the way to measure a plasma, the Langmuir probe is probably the simplest, intrusive and not remote technique [4]. The diagnostics of plasma is very complex and is very difficult, mainly because we want to avoid disturb the plasma, so we use the double probe because it does not disturb the plasma as much as the single probe with non-floating anode connection [5,6,7].

The structure of a double floating electric probe consists of two Langmuir probes with the same size and shape[8], one to draw electron current and one to draw ion current .The two together, however, draw no net current [9]. The probes are located very close together to ensure that the plasma properties are approximately equal [8], and the current from one to the other is measured as a function of the voltage difference between them. The (I_d-V_d) characteristic is then symmetrical and limited to the region between the $I_{sat's}$ on each probe[4].

The temperature (T) of the particles in plasma is often expressed as the value of the energy KT in units of electron volts .Thus a temperature of (1eV) corresponds to (11600K). Note that this energy of the particles, would be (3/2) KT [10, 11].

A glow discharge consists of numberof bright and dark regions between the cathode and the anode electrodes across the tube [2].

These regions are (Aston dark space, cathode glow region, cathode dark space, the negative glow, Faraday dark space, positive column, anode glow and anode dark space) [12].

The positive column is usually striated into bright and dark a few centimeters a part. They result from not very large periodic fluctuations electron density and energy initiated in the cathode region [10].

In this study the magnetic field is used to control the electron distribution in the discharge tube by the collimation way, In this way the magnetic field is parallel to the electric field, so the magnetic field prevents an excessive fraction of the electron being went to the walls of the discharge tube and constrains the discharge in the tube to a narrow column. Electrons attempting to travel across the lines of force are forced into a spiral path. The electrons scattered by collisions within the plasma are still trapped in the column by the magnetic field.[13]

Recently, some correlative works are developed to investigate the effects of many plasma parameters on its characteristics or on electron temperature.Petraconiet al [14] studied the effect of an external longitudinal magnetic field on the electrical breakdown of argon and nitrogen gases at low pressure.Low density plasma is generated by Hassouba et al [15] in a cylindrical DC magnetron discharge tube,they measured the discharge current and voltage (I_a-V_a) characteristic curves of the glow discharge for Ar and He gases pressures with and without magnetic field. Eizaldeen and Ashwaq studied some physical characteristics of argon plasma product by Hollow Cathode Discharge where they calculated the electron tempreture from I_d-V_d curves of the double probre at different gas pressures[16]. The effect of poles distances of a discharge tube on the electron temperature were investigated by naeema et al at(6 Pa) of helium under the influence of parallel and normal magnetic fields [17].

The purpose of the present work is to investigate experimentally the relation of electron temperature(T_e) calculated from (I_d-V_d) characteristics of double probes , with and without magnetic field, for different values of discharge voltage. The double probe used for measuring the electron temperature in a magnetic field, since it was the most reasonable method for measuring in a magnetic field. The data obtained from electrical double probes characteristics on DC discharge tube with helium gas are presented and discussed.

2. Experimented Setup:-

Fig.(1a,b) shows a photograph picture and schematic diagram of the experimental setup respectively.

A cylindrical discharge cell made of Pyrex glass tube of (30cm) length and (3cm) diameter. Two parallel movable circular electrodes of (2.5 cm) diameter were enclosed in the discharge tube.

The discharge tube was evacuated using rotary pump (type SMC) to a base pressure of (1×10^{-3} Pa). The tube was filled with the working gas (helium) at pressure (7 Pascal), the inter electrode spacing was (130 mm). The glow discharge region of current between (3-8.7)mA with different discharge voltages between cathode and anode (700-1200)V.

A double Langmuir probe was immersed atthe center of the tube to investigate the electron temperature of positive column of the helium glow discharge.

The double probe is identical in diameter which each has (1mm). The two tips oriented perpendicularly to the electric field in parallel plate system.

A permanent parallel magnetic field of (25 mT) located at a distance 1.3cm from the discharge tube near the anode electrode.

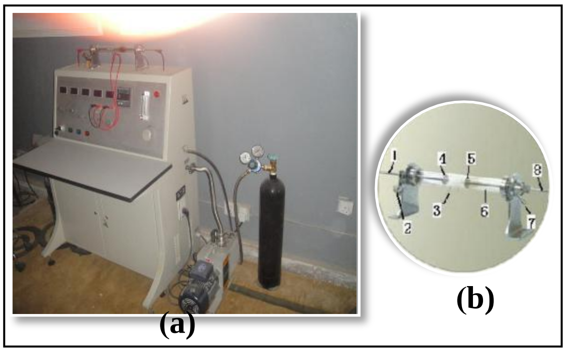

Fig. (1):(a) A photograph picture of the experimental setup.
(b): A schematic diagram of the experimental setup

1. High voltage anode: connect with the anode of the discharge tube.
2. Pump-line: to get vacuum environment in the discharge tube.
3. Probe: used for measurement of plasma parameters.
4. Anode: anode of the discharge tube.
5. Cathode: cathode of the discharge tube.
6. Discharge tube: plasma generate in it.
7. Gas supply port: used for charging gas into discharge tube.
8. High voltage cathode: connect with the cathode of the discharge tube.
9. The permanent magnetic field

3. Result and Discussion:

1- The I_d-V_d Characteristic Curves of the Discharge:

The I_d-V_d characteristic curves at different discharge voltage with and without magnetic field were measured by using double Langmuir probe are illustrated in figures(2 and 3). As shown from these two figures, that when the discharge voltage ($V_{dis.}$) increases the probe current (I_d) increases. The reason for this behavior is as the V_{dis} increases,the energy of the electrons in plasma increases,i.e. the probability of ionization will increase,i.e. the plasma density increases, so the charges which are collected by the double probe will increase, for recording the current.

The figures (2 and 3) can be drawn in another way as seen in figures (4,5,6,7,8,9). It can be seen from these figures that(I_d) has the lowest value for all discharge voltage when applying the parallel magnetic field because of the electrons are efficiently magnetized and trapped by the magnetic field at low pressures[18], which leads to reduce the number of charges collecting by the probe for recording the current.

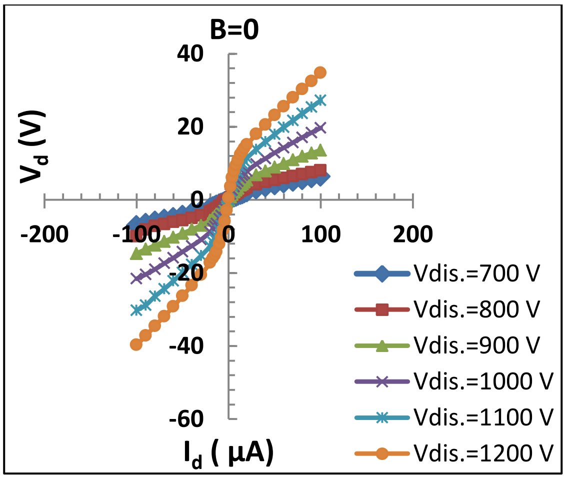

Fig.(2): The I_d-V_d characteristic curves at B=0

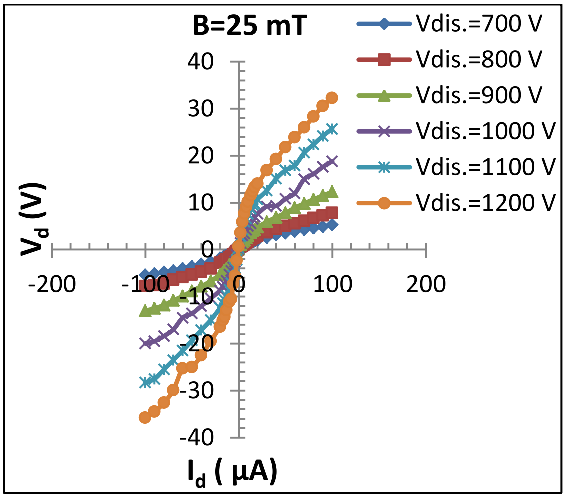

Fig.(3):The I_d-V_d characteristic curves with application parallel magnetic field (B‖) equals (25mT)

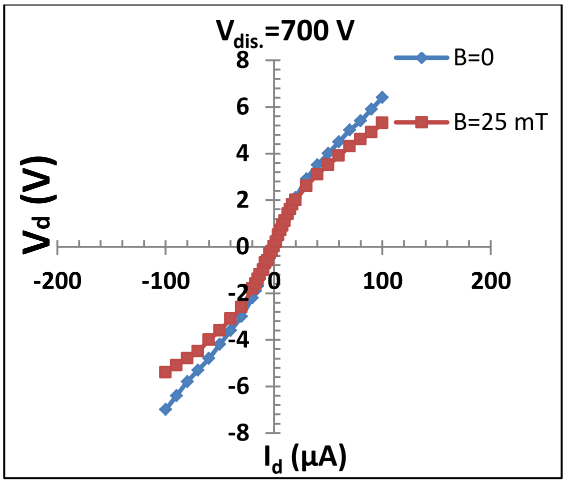

Fig.(4): The I_d-V_d characteristic curves for the both cases of magnetic field at $V_{dis.}$=700 V

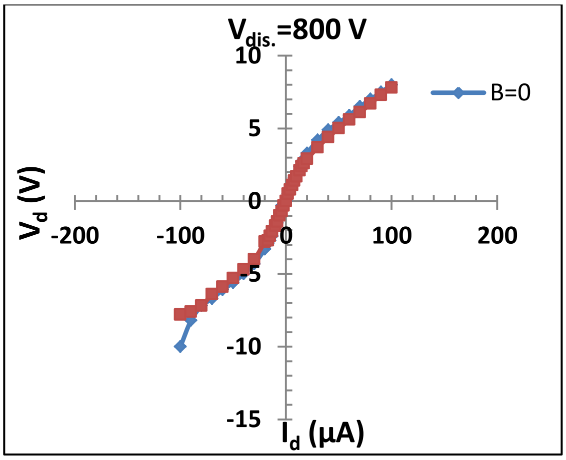

Fig.(5): The I_d-V_d characteristic curves for the both cases of magnetic field at $V_{dis.}$=800 V

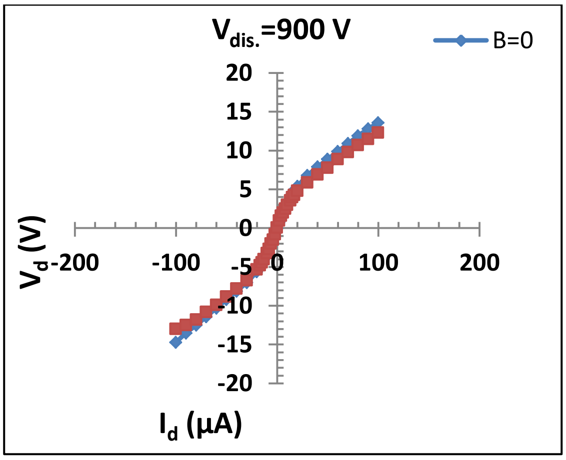

Fig.(6): The I_d-V_d characteristic curves for the both cases of magnetic field at $V_{dis.}$=900 V

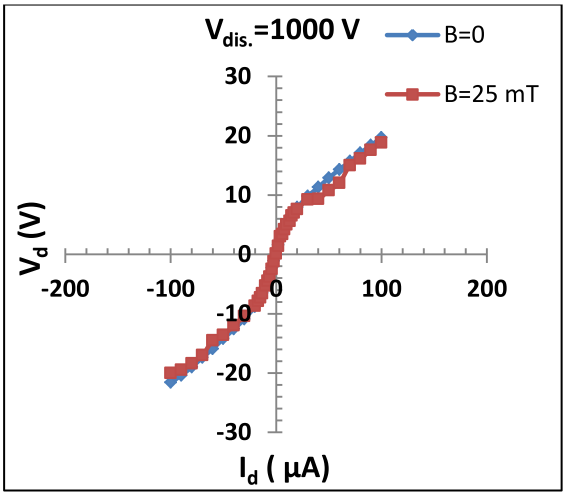

Fig.(7): The I_d-V_d characteristic curves for the both cases of magnetic field at $V_{dis.}$=1000V

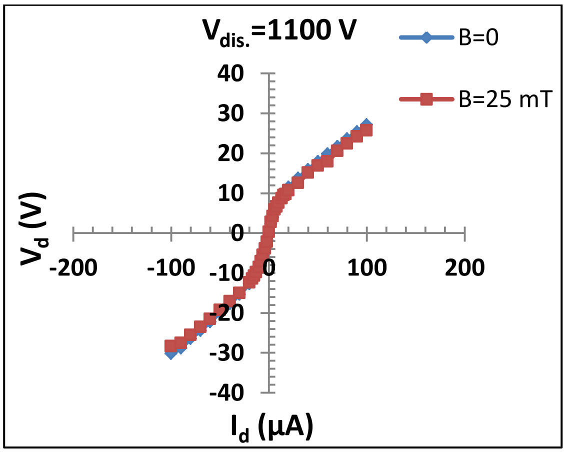

Fig.(8): The I_d-V_d characteristic curves for the both cases of magnetic field at $V_{dis.}$=1100V

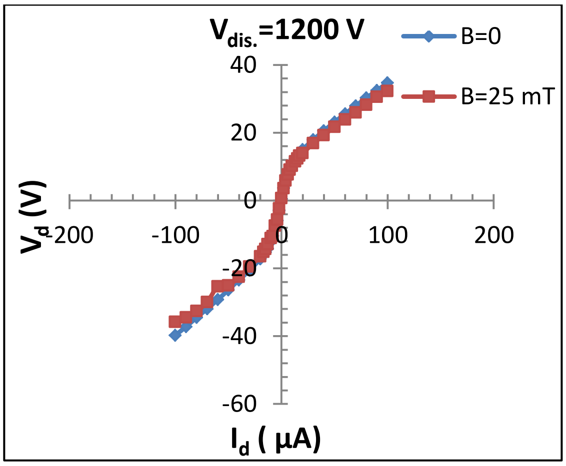

Fig.(9): The I_d-V_d characteristic curves for the both cases of magnetic field at $V_{dis.}$=1200V

2-Measurements of Electron Temperature

The electron temperature (T_e) can be estimated by using I_d- V_d characteristics curves of double Langmuir probe by using the following equation: [19,20]

$$T_e = \frac{(I_1 + I_2)}{4} \frac{dV_d}{dI_d}\bigg|_{V_d=0}$$

Where I_1 and $I_2$are the ion saturation current for probe 1 and probe 2 respectively. It can be seen from fig.(10) that as ($V_{dis.}$) increases, the electron temperature decreases, because of the electrons would make more ionization,so they lose energy,accordingly their temperature will decrease. Also , it can be seen that the electron temperature at B=0 is smaller than the corresponding values at B=25 mT. This effect is more remarkable in lower gas pressure [21].

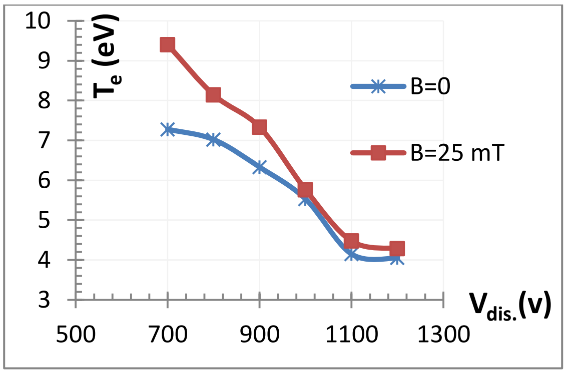

Fig.(10): The electron temperature as a function of the discharge voltage for two cases (B=0 and B‖)

4. Conclusions

Optical absorption vary with light wavelength and increases with increasing

The influence of discharge voltage on the I_d- V_d characteristics in low pressure helium gas have been investigated in a system consists of a discharge tube with two parallel electrodes.The above process was performed in two cases:parallel magnetic field equals 25 mT and without magnetic field. The most important conclusions are:

1. We observed that as ($V_{dis.}$) increases the (I_d) increases in the both cases (with and without magnetic field).
2. The values of (I_d) without applied magnetic field are higher than their values with magnetic field because of the confinement effect.
3. The electron temperature decreases with increasing the discharge voltage with and without magnetic field but their values at (B=0) are smaller than the corresponding values at (B=25 mT).

5. Reference

[1] F.L.King,J.Teng and R.E. Stei¬ner,"Glow Discharge Mass Spectr¬romtery:Trace Elements Determina¬tion in Solid Samples", Journal of Mass Spectrometry,V.30,P.P:1061-1075,(1995).

[2] M.A.Hassouba and E.A.Menanna,"Electrical Characteristics of (N2-H2) Gas Mixture DC Glow Discharge", International Journal of Physics Sciences,4(11),P.P:713-721,(2009).

[3] M.Ira,Cohen,"ASymptotic Theory of Spherical Electrostatic Probes in a SlightlyIonized,Collision-Dominnated Gas", The Physics of Fluid,V.6,P.P:1492-1500,(1963).

[4] F.F.Chen,"Langmuir Probe Diagnos¬tics", Mini-Course on PlasmaDiagnos¬tics,IEEE-Icops meet¬ing,Jeju,Korea,(2003).

[5] A.Y.Wang,"Introduction to Experimental Plasma Physics",UCLA,(1984).

[6] E.Leal-Quiros,"Novel Probes and Anlyzers for Controlled Fusion Research",U of Missouri-Columbia,(1989).

[7] R.M.Clements,"Plasma Diagnostics withElectric Probes", J.Vac.Sa.Technol.,15(2),P.P:193-198,(1978).

[8] P.Zheng,"Langmuir Probe for Electron – Cyclotron – Resonance Plasma", M.Sc.Thesis,Gradute Faculty of Texas University,(1990).

[9] D.R.Micgregor,"Growth Optimization and Characterization of Reactively Sputtered Zirconium Nitride thin films for III-VBuffer Layer Applications" , M.Sc. Thesis, North Carolina State University, (2002).

[10] M. A. Heald and C.B. Wharton, "Plasma Diagnostics with Microwaves", Wily, New York, (1965).

[11] A.J.Thornton, "Masnetron Sputtering: basic Physics and application to cylindrical magnetrons", J. Vac. Sa. Technol, 15(2), P.P: 171-177 ,(1978).

[12] فتحي محمد جاسم البدراني،(تاثير المجال المغناطيسي المحوري في متغيرات بلازما التفريغ التوهجي المستمر في غاز النتروجين عند الضغوط المعتدلة)، رسالة ماجستير، كلية التربية، جامعة الموصل، ١٩٩٠ .

[13] H. Ryssel and H.Glowisching,"Ion Implantation Teehniques",Springer-Verlage,Newyork.,(1982).

[14] G. Petraconi, H. S. Maciel, R. S. Pessoa, G. Murakami, M. Massi, C. Otani, W. M. I. Uruchi, and B.N. Sismanoglu,"Longitudinal Magnetic Field Effect on the ElectricalBreakdown in Low Pressure Gases",Brazilian Journal of Physics, V. 34, No. 4B,P.P:1662-1666 (2004).

[15] M. A. Hassouba and N. Dawood," Study the Effect of the Magnetic Field on the Electrical Characteristics of the Glow Discharge",Advances in Applied Science Research, 2 (4),P.P: 123-131,(2011).

[16] F.EizaldeenKotp and A.Ashwaq AL-Ojeery," Studies The Effect Of Magnetic Field On Argon Plasma Characteristics", Australian Journal of Basic and Applied Sciences, 6(3), P.P: 817-825,(2012).

[17] N. H.Ali , M. A.Yeser, N. F.Ali," The Effect of the Poles Distances on Plasma Characteristic of Discharge Tube",Ibn Al-Haitham Journal f or Pure and Applied Science,25(1),P.P:180-193,(2012).

[18] K. Kobayashi, T. Ito, M. A. Cappelli3, and S.Hamaguchi1,"Magnetized microdischarge plasmas in low pressure argon and helium", Journal of Physics: The Second International Symposium on Atomic Technology, (2008).

[19] A.Grill," Cold Plasma in Mterials Fabrication",IEEE Prees,Newyork, (1994).

[20] علي خلف الجبوري، تصميم وتشغيل منظومة الكترونية لتحديد ودراسة دالة التوزيع السرعي للألكترونات في البلازما، رسالة ماجستير، كلية العلوم، جامعة الموصل، (١٩٩٩).

[21] T.Kaneda, "The influence of a transverse magnetic field on a glow discharge tube",J.Light and Vis.Env.,2(1),P.P:45-50,(1978).