The Effect of the Poles Distances on Plasma Characteristic of Discharge Tube

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Abstract

The effects of poles distances of a discharge tube (cathode and anode) were investigated. The distances(90,95,100,110,115,120,130,140)mm are considered. The influence of (25mT) parallel and (2mT) normal magnetic fields with respect to the discharge tube on electron temperature under a pressure of (6pascal) and (900volt) was studied by implementing double Langmuire probe into plasma. Curves fitting were performed to find the optimum values of electron temperature for all cases in this work.We found that the electron temperature as a function of poles distances is exponential form.
Keywords: Glow discharge, Langmuire probes, Plasma diagnoistics.

Introduction

A glow discharge is a self sustaining discharge through gas which occurs at pressures well below atmospheric pressure [1,2].The low pressure glow discharge plasma is created by applying a potential difference between two electrodes of certain distance a part [3]. It has obvious glowing regions and fills the full cross-section of the tube [2].

Glow discharge used in various applications such as deposition of thin films, etching and modification of surfaces in semiconductor industry and materials technology [3].

Langmuire probes are commonly used diagnostics in low-pressure plasma discharge <1 torr [4]. Of all the way to measure a plasma, the Langmuir probe is probably the simplest, intrusive and not remote technique [5]. The diagnostics of plasma are very complex and are very difficult, mainly because we want avoid disturb the plasma , so we use the double probe because it does not disturb the plasma as much as the single probe with is non-floating anode connection [6 ,7,8].

The structure of a double floating electric probe consists of two Langmuir probes with the same size and shape[9], one to draw electron current and one to draw ion current .The two together , however, draw no net current [10]. The probes are located very close together to ensure that the plasma properties are approximately equal [9], 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 [5].

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 the (1eV) corresponds to (11600K). Not that this energy of the particles, which would be (3/2) KT [1,11,12]. A glow discharge consists of no .of bright and dark regions between the cathode and the anode electrodes across the tube [2,3].

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) [13].

Most of the potential drop occurs near the cathode over a region called the cathode fall where ions are accelerated into the cathode at sufficient energy to cause emission of secondary electrons from the cathode. These electrons are accelerated away from the cathode producing further electrons and ions as a result of ionizing collisions [2]. 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 [11].

(1-1) The Variation of The Separation Distances between Cathode and Anode

The cathode fall region is essential for the existence of the discharge .The positive column provides a conducting connection to the anode. Thus if the separation distance between the electrodes is varied (keeping pressure and current constant) The cathode fall will remain unchanged and the length of positive column will vary [1].

(1-2) The Influence of Magnetic Field [14,15]:

$$\vec{F} = q(\vec{v} \times \vec{B}) - - - - - - - (1)$$

The above equation represents the magnetic force effect on a charges (+,-) when E=0.The cyclotron frequency can be defined as follows:

$$\vec{\omega}_c = \frac{|q|\vec{B}}{m} - - - - - - - (2)$$

We defined the Larmor radius to be:

$$\vec{r}_L = \frac{v_\perp}{\vec{\omega}_c} = \frac{mv_\perp}{|q|\vec{B}} - - - - - - - (3)$$

If now we allow an electric field (E)to be present, the motion will be found to be the sum of two motions: the usual circular Larmor gyration plus a drift of the guiding center. The equation of motion is now:

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B}) - - - - - - - (4)$$

So the particle drifts in crossed electric and magnetic fields will be as shown in fig.(1).Where the electrons are more effected by magnetic field than ions.

$$i.e.\vec{r}_{L_i} \rangle \vec{r}_{L_e} - - - - - - - - (5)$$

This behavior can be attributed to the smallness of electron mass.

In this study the magnetic field is used to control the electron distribution in the discharge tube in two ways [16]:

1-collimation:

In this case 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.

2-Path lengthening:

Here the electric field and the magnetic field at right angles and the primary function of the magnetic is to prevent the electrons travelling directly to the anode in a direction determined by the electric field. The result is a greatly increased path length for the electron and therefore a reduction in the gas pressure is necessary to give a sufficient ionization probability to maintain the discharge.

Experimented Setup

Fig.(2a,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 abase pressure of (1×10^{-3} pascal). The tube was filled with the working gas (helium) at pressure (6 pascal), the applied voltage between the cathode and anode was (900V). The glow discharge region of current between (3-6.65)mA with different distances between cathode and anode (90-140)mm.

A double Langmuire probe was immersed at the center of the tube to investigate the plasma (electron temperature) of positive column of the helium glow discharge.

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

A permanent magnetic field is located at a distance 1.3cm from the discharge tube near the anode electrode.

In this present work, we studied the influence of variation of the separation distance between cathode and anode and the effect of the parallel and normal magnetic fields with respect to the electric field between cathode and anode on the electron temperature. The intensity of the parallel magnetic ($B_{\parallel}$) field was (25mT) and (2mT) for the normal one ($B_{\perp}$).

Experimental Result and Discussion

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

The I_d-V_d characteristic curves at different separation distances between cathode and anode for three cases ($B=0$, $B_{\perp}$,$B_{\parallel}$) which were taken by using double Langmuire probe are illustrated in figures(3,4,5).

As shown from all these three figures that when the separation distance (d) increases the probe current (I_d) decreases.

The reason for this behavior was as the space between cathode and anode increases, the plasma density decreases, (i.e. it distributed on a larger volume) so the charges which collected by the double probe will decrease for recording the current.

The figures (3,4 and5) can be drown in other method as seen in figures(6,7,8,9,10,11,12,13).

By comparably the figures (6,7,8,9,10,11,12,13) with each other we can see that (I_d) at (B=0) has the highest value for all separation distances (i.e. for all of them).Because there is no magnetic field constraining the plasma which leads to reduce the no. of charges collecting by the probe for recording the current.

Also we can see that, in spite of the low value of normal magnetic field in comparison with the value of parallel magnetic field,(I_d) at the first one(I_d) will be smaller than the value of the second one at (d=90mm) as seen in fig (6) , more increasing in (d) makes the two currents approaches from one to another, until they would be nearly compatible at distances (130mm).As shown in figs.(7,8,9,10,11,12).

Further increasing of the separation distance (d), i.e.at (d=140mm), causes (I_d) of the normal magnetic field will be larger than (I_d) of the parallel one, see fig. (13).

The reasons for this can be explained as follows:

The plasma distributed on a small volume at small separation distances, so the parallel magnetic field will confine the plasma at rather narrow column, as the separation distances increase the plasma will be distributed on a larger volume, then the parallel magnetic field will confine the charges at a more narrow column, by anther speech a large amount of charges will be constrained by magnetic field which reduces much more charges collecting by the probe to record the current.

2-Measurements of Electron Temperature:

The electron temperature (T_e) was measured from the I_d- V_d characteristics curves by the application of the following equation: [17,18]

$$T_e = \frac{(I_1 + I_2)}{4} \frac{dV_d}{dI_d}\bigg|_{v_d=0} --------(6)$$

Where I_1 and I_2 is the ion saturation current for probe 1 and probe 2 respectively

It can be seen from fig.(14) that as (d) increases, the electron temperature increases because of the increase in (d) means increase in space, so the mean free path will increase so the electrons will have more chance for acquisition of an acceleration through the electric field i.e they acquire kinetic energy .

Also it can be seen from fig.(14) that the electron temperature has the largest value when B=0 ,because there is no magnetic field make the electrons to have more collisions which leads to lost their energy then decrease in their temperature, this result is agreement with published work [13].

We can see also from fig.(14) the influence of normal magnetic field (path lengthing effect) in decreasing the electron temperature is much more than the influence of parallel magnetic field (collimating effect) in spite of the smaller value of the first one (2mT)than the value of the second one (25mT).

Curve fitting was performed for the three cases (B=0, B‖ and B $\perp$) to find the optimum value of the electron temperature as a function to the distance between the two poles.

(T_e) as a function of (d) is given by the formula:

$$T_e = a_0 \exp(a_1 d) - - - - - - - (7)$$

When B=0: a_0=5.57015 a_1=0.00247635

B‖: a_0=4.57372 a_1=0.00370314

B⊥: a_0=3.07331 a_1=0.00595367

Conclusion

I_d-V_d characteristic curves of the glow discharge were studied at different separation distances, whenever the distance between the two poles increase, the probe current (I_d) decrease and so this make exponential increase in electron temperature .

(I_d) of applied parallel magnetic field will be larger than (I_d) of normal one at small distance. Further increase in (d) causes (I_d) of normal magnetic field will be larger than (I_d) of parallel one.

Also (T_e) was determined in different three cases : (B=0, B‖ and B⊥)

(T_e) will has the largest values when B=0,and its value at B‖ larger than at B⊥).

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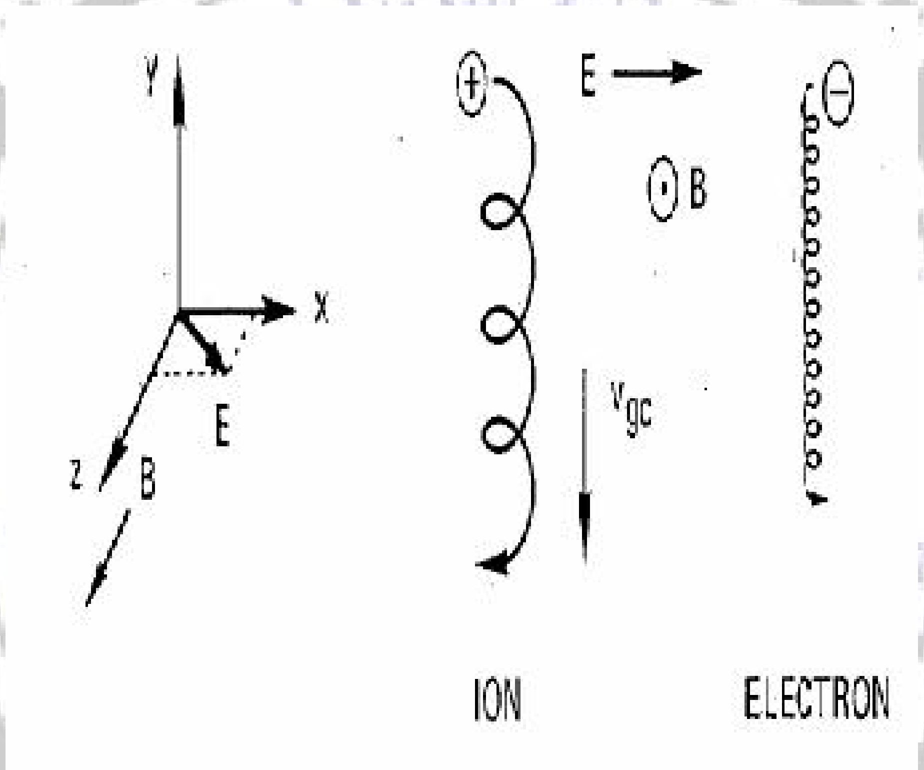
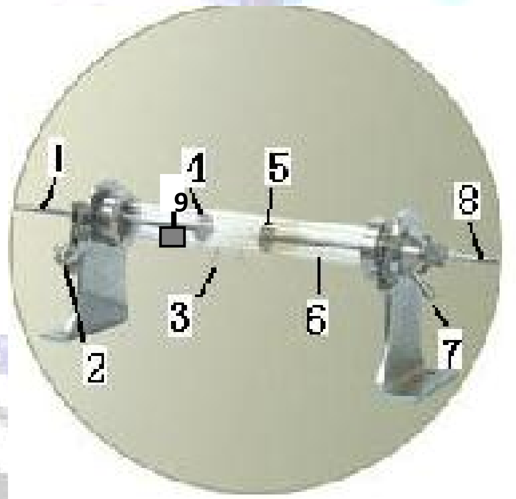


Fig.(1) :Particle drifts in crossed electric and magnetic fields

Fig. (2a): A photograph picture of the experimental set up



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.

Fig.(2b): A schematic diagram of the experimental setup

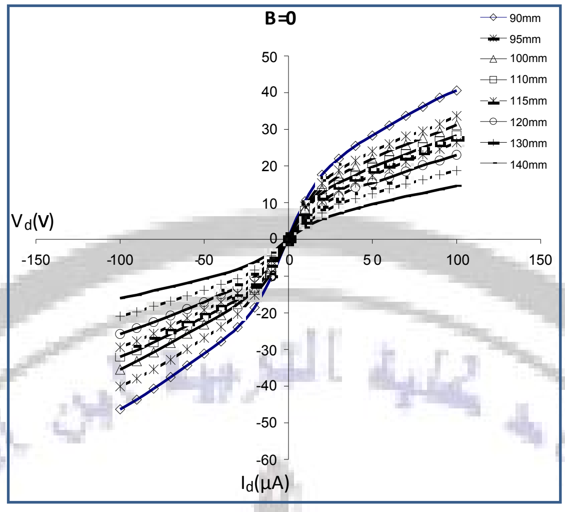


Fig.(3): The I_d-V_d characteristic curves at B=0

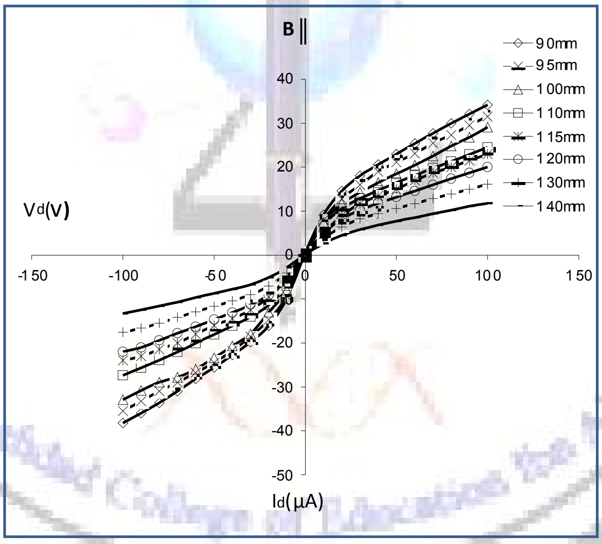


Fig.(4) :The I_d-V_d characteristic curves with application parallel magnetic field (B║) equals (25mT)

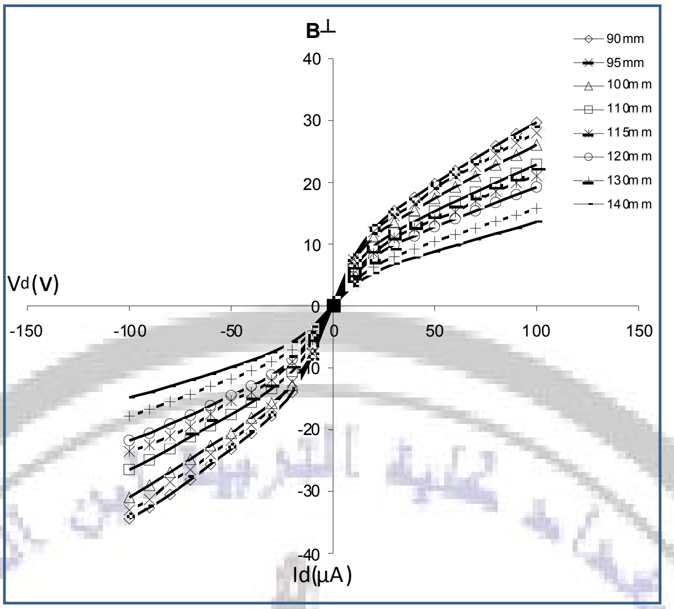


Fig.(5) :The I_d-V_d characteristic curves with application normal magnetic field (B⊥) equals (2mT)

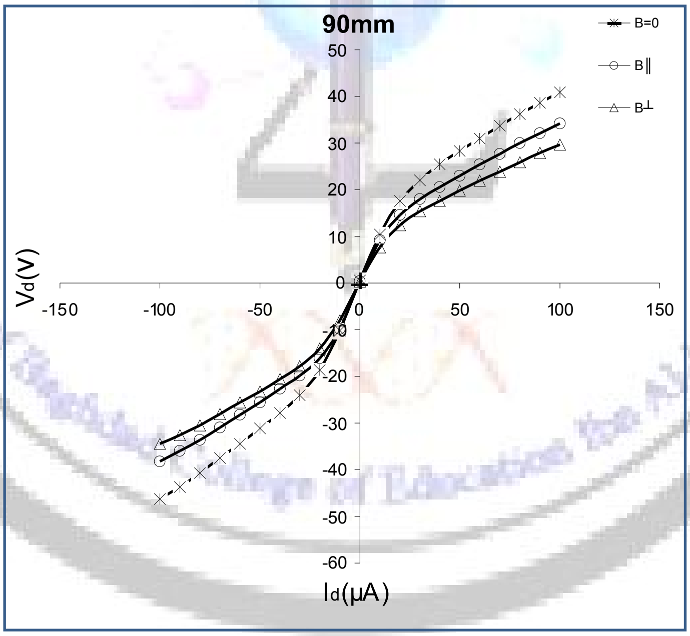
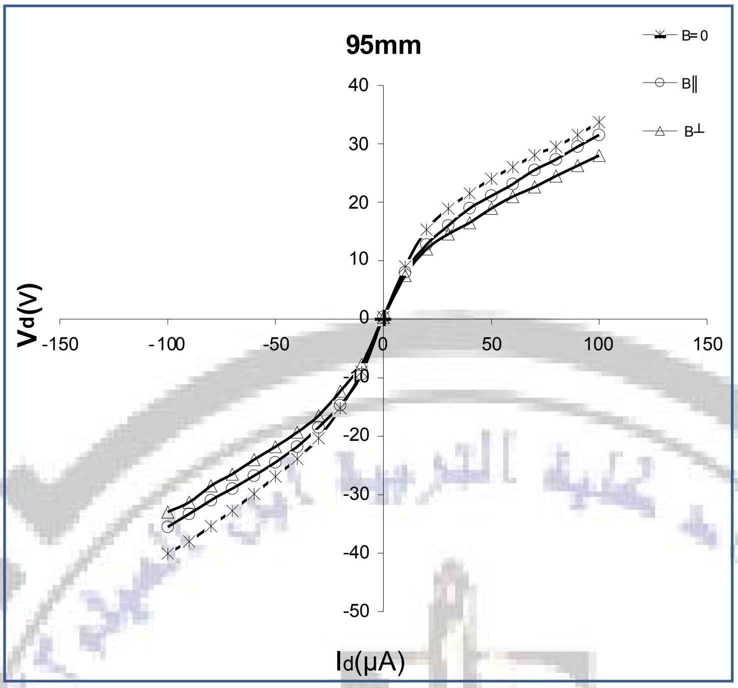


Fig.(6) The I_d-V_d characteristic curves for the three cases of magnetic field at d=90mm



Fig(7) The I_d-V_d characteristic curves for the three cases of magnetic field at d=95 mm

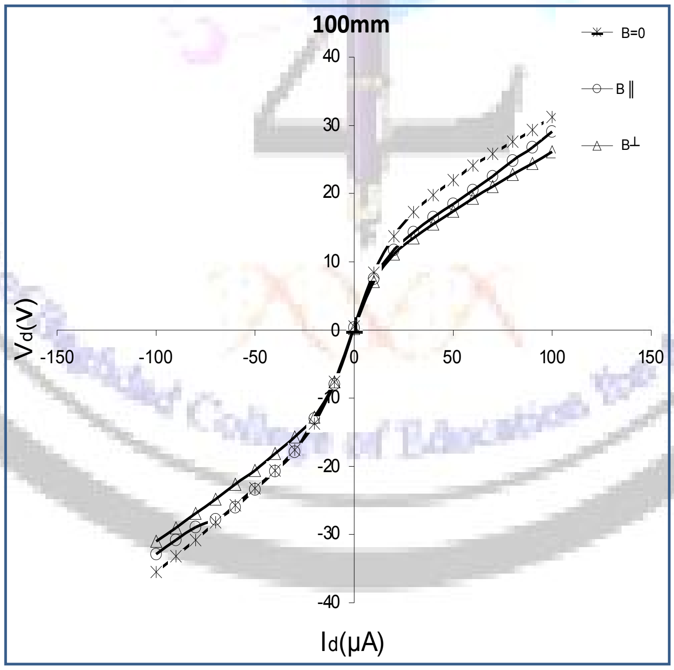


Fig.(8): The I_d-V_d characteristic curves for the three cases of magnetic field at d=100 mm

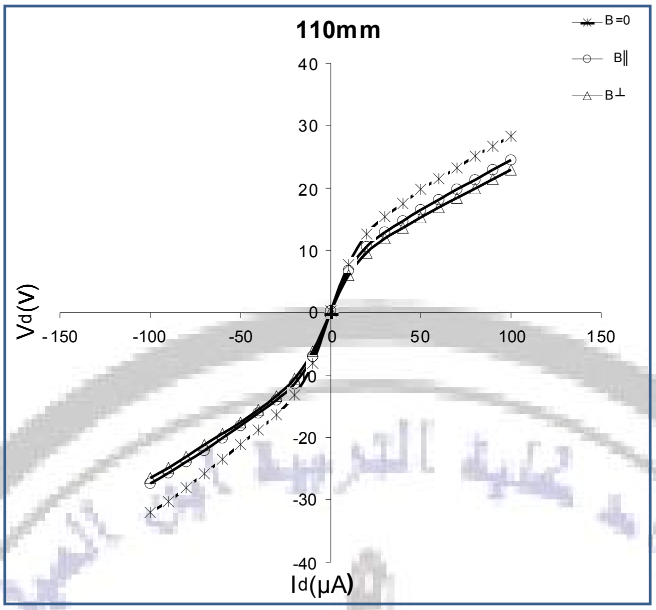


Fig.(9): The I_d-V_d characteristic curves for the three cases of magnetic field at d=110 mm

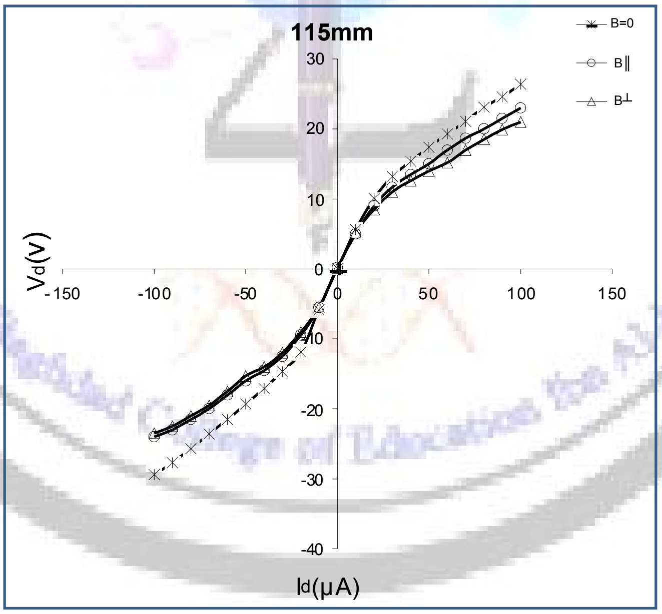


Fig.(10): The I_d-V_d characteristic curves for the three cases of magnetic field at d=115mm

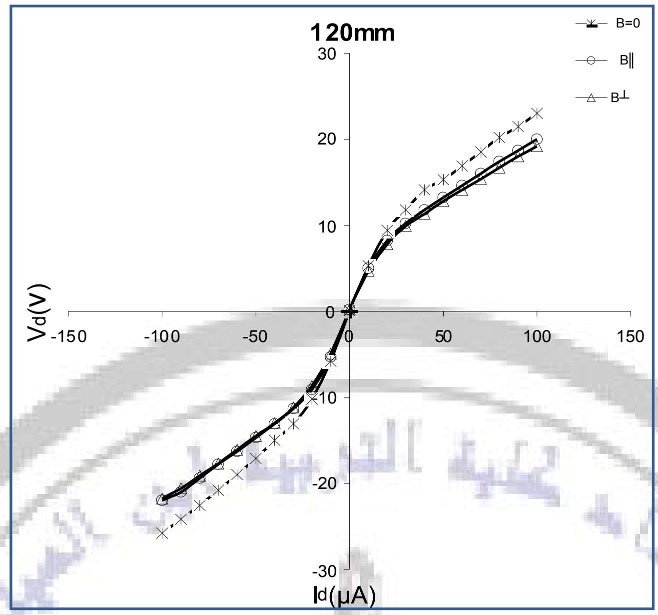


Fig.(11) :The I_d-V_d characteristic curves for the three cases of magnetic field at d=120 mm

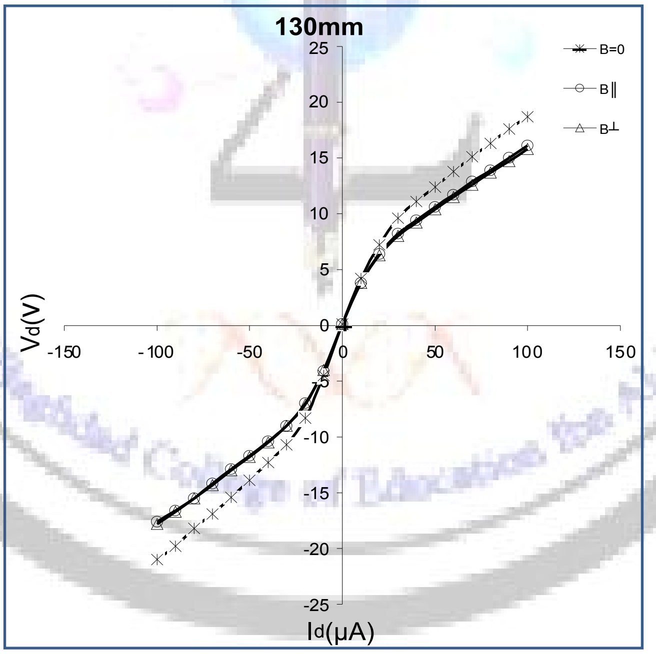


Fig.(12): The I_d-V_d characteristic curves for the three cases of magnetic field at d=130 mm

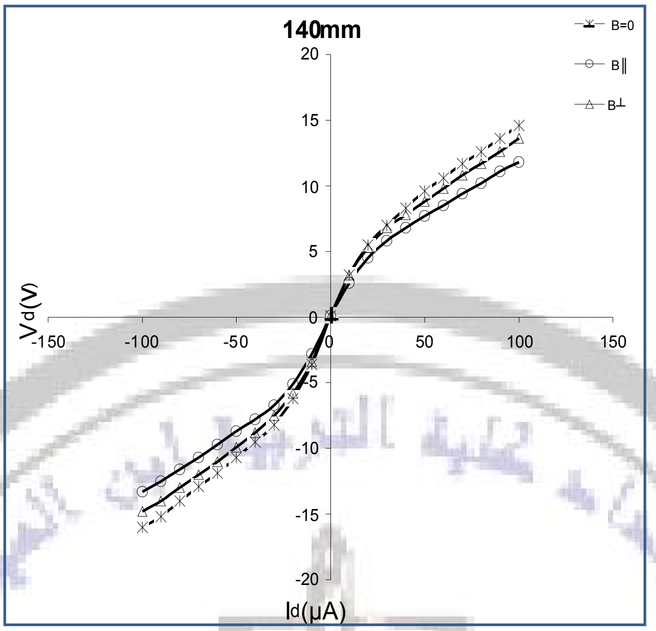


Fig.(13): The I_d-V_d characteristic curves for the three cases of magnetic field at d=140mm

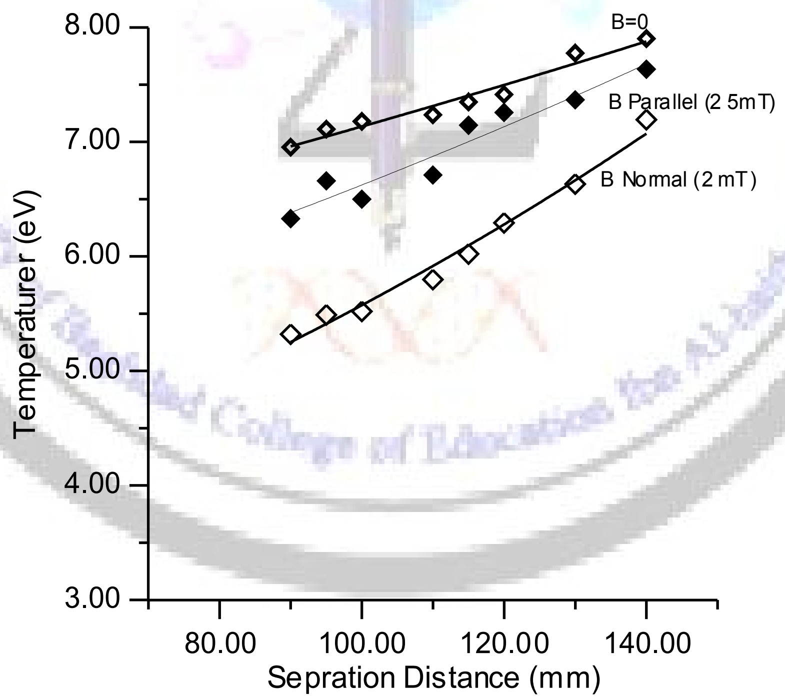


Fig.(14): The electron temperature as a function of the separation distance for three cases(B=0 , B‖ and B⊥)

تأثيربعد الأقطاب في خواص البلازما في منظومة التفريغ الكهربائي

نعيمة هادي علي ، مهدية أحمد يسر ، نبراس فاضل علي
قسم الفيزياء ، كلية العلوم ،جامعة الكوفه

استلم البحث في: 21 حزيران2011 ،قبل البحث في: 18 تشرين الاول 2011

الخلاصه

تم في هذا البحث دراسة تأثير بعد أقطاب إنبوبة التفريغ (الكاثود والأنود) للمسافات 120, 115, 110, 100, 95, 90) mm(140, 130, وتاثيرالمجـال المغناطيسي الموازي والعمودي ذو الشدتين (25mT) و (2mT) على الترتيب في درجة حرارة غاز الالكترونات في منظومة بلازما تعمل بضغط (6 pascal) وفولتية (900 V) وذلك باستخدام مجس لانكمور المزدوج . وقد أجري توفيق منحنى لقيم درجة حرارة غاز الألكترونات التي حصلنا عليها بالنسبه الى بعد الأقطاب لإيجاد أفضل داله.وقدوجد أن درجة حرارة غاز الألكترونات بصفتها داله لبعد الأقطاب تسلك سلوك داله أسيه.

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