The Effect of Magnetic Fields on Helium Plasma Parameters

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Abstract:
The plasma diagnosis system (DHPD-1 Plasma Diagnostic Experimental Instrument) has been used to generate plasma by DC discharge technique employing Langmuir's double probe to measure the (I-V) characteristics and plasma parameters (electron temperature and electron density). The influence of both longitudinal and transversal magnetic fields on the electron temperature and electron density of helium gas plasma at low pressures (5, 10, 20, 30) Pa have been investigated. In presence of magnetic field, it was found that the electron temperature and electron density decrease with increasing gas pressure. The electron temperature is decreasing with increasing the longitudinal magnetic field, but it is increasing with increasing the transversal magnetic field. The electron density is demonstrating an opposite behavior as compared with electron temperature in presence of magnetic fields.

Keywords: Plasma parameters, magnetic field and Langmuir double probe.

تأثير المجالات المغناطيسية على معاملات بلازما الهيليوم

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الخلاصة:
استخدمت منظومة تشخيص البلازما (DHPD-1 Plasma Diagnostic Experimental Instrument) لتوليد بلازما باستعمال تقنية تفريغ التيار المستمر و مجس لانكمور الثنائي لقياس خصائص (I-V) ومعاملات البلازما(درجة حرارة الالكترون والكثافة الالكترونية).لقد درس تأثير كلا المجالين المغناطيسيين الطولي والعرضي على درجة حرارة الالكترون والكثافة الالكترونية لبلازما غاز الهليوم عند ضغوط واطئة (5, 10, 20, 30)Pa فوجد انه في حالة وجود مجال مغناطيسي تقل درجة حرارة الالكترون والكثافة الالكترونية بزيادة ضغط الغاز. اما درجة حرارة الالكترون فأظهرت تناقصا بزيادة المجال المغناطيسي الطولي ولكنها تزداد بزيادة المجال المغناطيسي العرضي. و اظهرت الكثافة الالكترونية سلوكا مغايرا مقارنة بدرجة حرارة الالكترون في حالة وجود المجالات المغناطيسية.

الكلمات المفتاحية: معاملات بلازما, المجال المغناطيسي, مجس لانكمور المزدوج.

1. Introduction

The effect of magnetic field geometry on plasma characteristics has taken a wide interest by researchers theoretically and experimentally [1-3]. Teruo Kaneda [4] studied the influence of a transverse magnetic field on the plasma parameters such as an axial electric field, an electron temperature and an electron density. L. Beckman [5] carried out a theoretical study that's shown the magnetic field deflects the column towards the wall with the result that the total loss of electrons and ions is increased. This causes an increasing in the electron temperature and in the axial field strength. To measure the characteristics of plasma, the Langmuir's double probe may be considered an appropriate device [6-8]. S. S. Pradhan and D. C. Jana [9] used double probe technique to measure plasma parameters in subnormal gas discharge where they calculated the electron temperature and electron density in presence of both a transverse and a longitudinal magnetic field in low pressure. S. K. Al-Hakary *et al*. [10] measured plasma parameters (drift velocity, mobility and density of electron) in a positive column in presence of a longitudinal magnetic field of (0-6.5) G for Nitrogen plasma.

In present article, the effects of both transverse and longitudinal magnetic fields at low pressures on helium plasma parameters (the electron temperature and the electron density) have been investigated using Langmuir's double probe method.

2. Theoretical part

From the properties of the double probe curve, one may use the following relationships to find the electron temperature T_e and the electron density n_e [11]:

$$T_e = \frac{e}{k}\left[\frac{I_1 I_2}{I_1+I_2}\cdot\left(\frac{dV}{dI}\right)_{I=0}\right] \qquad (1)$$

where I_1 and I_2 are the ion saturation currents for double probe respectively.

$$n_e = -1.22\frac{J_e}{e\left(8KT_e/\pi m_e\right)^{\frac{1}{2}}\left(\mu_e/\mu_i\right)^{1.08}} \qquad (2)$$

where m_e and K are the electron mass and the Boltzmann's constant respectively.

Here the electron current density J_e is the ratio of the ion current to area of probe A_p is given as follows:

$$J_e = -\frac{1}{2}\left(\frac{I_1}{A_p}\right) \qquad (3)$$

and the ratio between the electron mobility μ_e and ion mobility μ_i equals

$$\mu_e/\mu_i = 7.64 m_i^{0.46} \qquad (4)$$

where m_i represents the ion mass [12].

3. Experimental setup

A schematic diagram of the glow discharge device used in this investigation is shown in figure (1). High purity helium gas is used in DC glow discharge process. A cylindrical discharge unit is made from the Pyrex glass tube which its length (30cm) and diameter (3cm). It includes two parallel movable circular electrodes with diameter (2.5 cm) and the separation distance between them (i.e. the cathode and the anode) (10 cm).

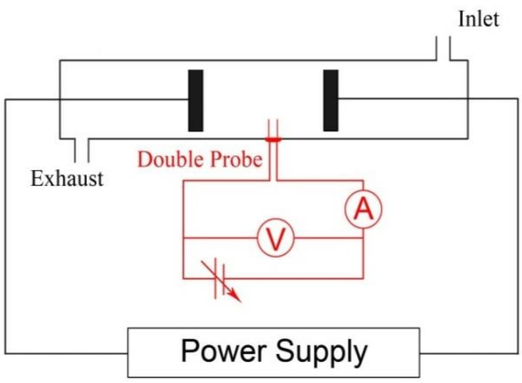


Fig.(1) Shows glow discharge system with probe circuit

The discharge tube was evacuated using rotary pump (type SMC) to low pressure of (1×10^{-1} Pa). The tube was filled with helium at pressure range from (5 Pa) to (30 Pa).

The discharge tube was subjected to magnetic field in two directions, once in the longitudinal and another in the transverse with respect to the discharge tube axis as shown in figure (2). The magnetic fields for both cases were varied from (0-100) G.

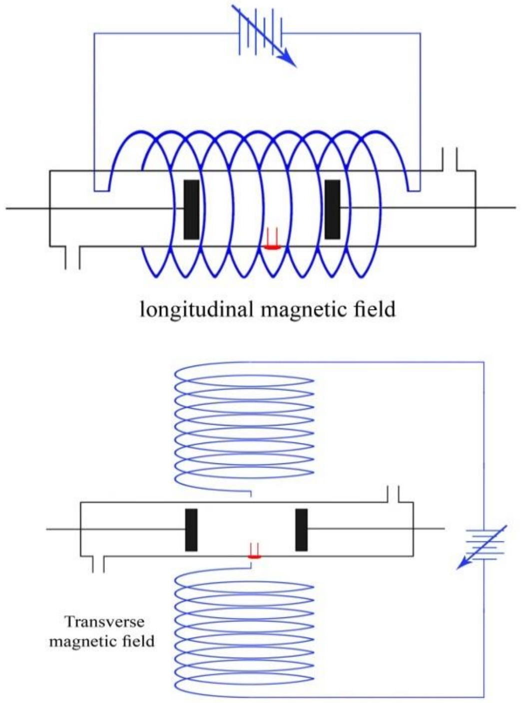


Fig. (2) Discharge tube in longitudinal and transversal magnetic fields.

A double Langmuir's probe was immersed at the center of the tube to investigate the plasma parameters (the electron temperature T_e and electron density n_e) of positive column of the helium glow discharge. Both wires of double probe are identical having a diameter (1mm) and they are perpendicular on the tube discharge system.

4. Results and discussion

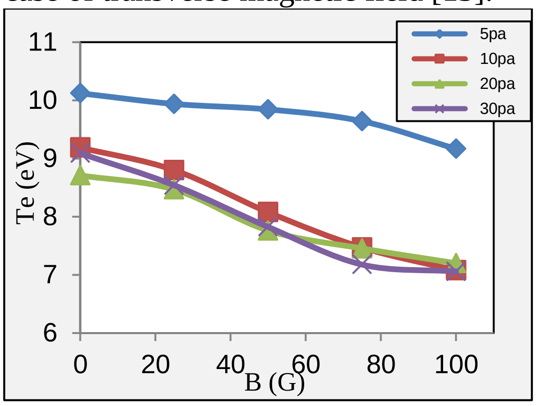
4.1 Electron Temperature

4.1.1 Electron temperature variation with magnetic field

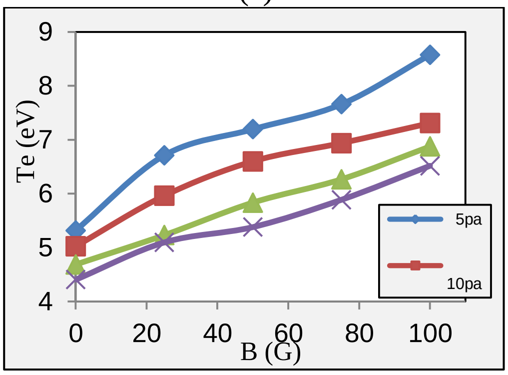
Figures (3) represent the variation of electron temperature T_e with longitudinal and transverse magnetic field B for several values of pressure (5, 10, 20, 30) Pa.

Figure (3 -a-) shows T_e decreases with increasing longitudinal magnetic field. It could be explained as follows: the presence of longitudinal magnetic field will cause the electrons to move with helical path which increases the probability of collision with atoms and ions, this will reduce the effective free path and hence decreasing the kinetic energy of the electrons and electron temperature. The results showed agreement with Fathi M. Jasim [12].

In case of transverse magnetic field, figure (3 -b-) shows that the electron temperature increases when the transverse magnetic field is increasing. The results are in agreement with the experimental investigation of Teruo Kaneda [4]. This effect is more remarkable in lower gas pressure, also there is an agreement with the theoretical deductions of Beckman (1948) [5] and Sen and Gupta (1972) in case of transverse magnetic field [13].



(a)

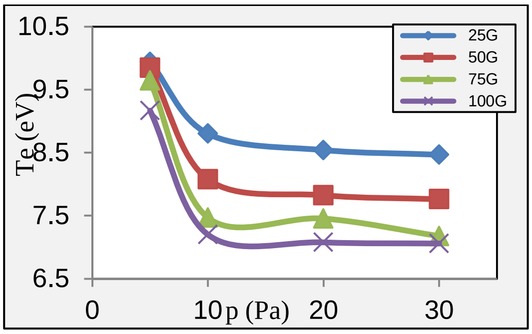


(b)

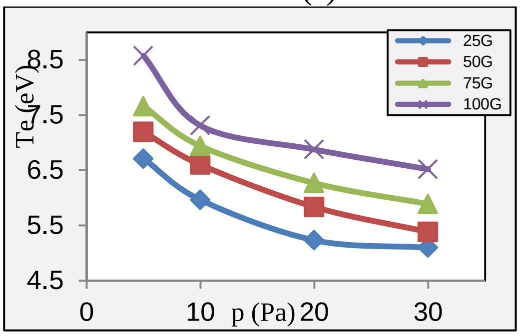
Fig.(3) Electron temperature variation as function of magnetic field at different pressures values in presence of (a) longitudinal magnetic field (b) transverse magnetic field.

4.1.2 Electron temperature variation with pressure

Figures (4) represent the electron temperature variation with pressure to different values of the longitudinal and transverse magnetic fields (25, 50, 75, 100) G. It shows that the electron temperature decreases with increasing gas pressure. This may be understood because that the pressure decreasing leads to increase the free path of electrons giving the electrons greater chance of gaining acceleration through the electric field, thus the electrons will gain a higher kinetic energy and higher temperature. This effect is apparent in both cases of longitudinal and transverse magnetic fields. The results show good agreement with Teruo Kaneda [4].



(a)



(b)

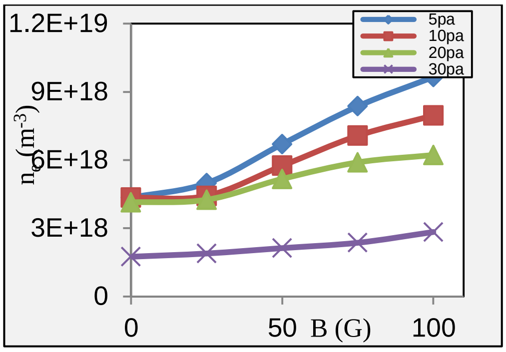
Fig.(4): Electron temperature variation as function of pressure at different magnetic fields values in presence of (a) longitudinal magnetic field (b) transverse magnetic field.

4.2 Electron Density

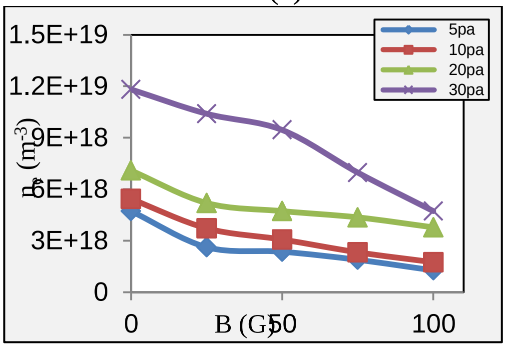
4.2.1 Electron density variation with magnetic field

Figures (5) represent the electron density variation with magnetic field values at different values of pressure. Figures (5 -a-) demonstrates that the electron density increases with increasing of longitudinal magnetic field. The electrons moving through a longitudinal magnetic field have helical paths around longitudinal magnetic field thus it may gain enough acceleration to ionize gas atoms leading to increasing electron density by inelastic collision with another particle (ion and atom helium).

In case of transverse magnetic field, the effect of electron collisions with walls of plasma tube which limit the probability of electron to obtain enough acceleration to ionize gas atoms must be taken into consideration. Thus the electron density decreases with magnetic field increasing.



(a)

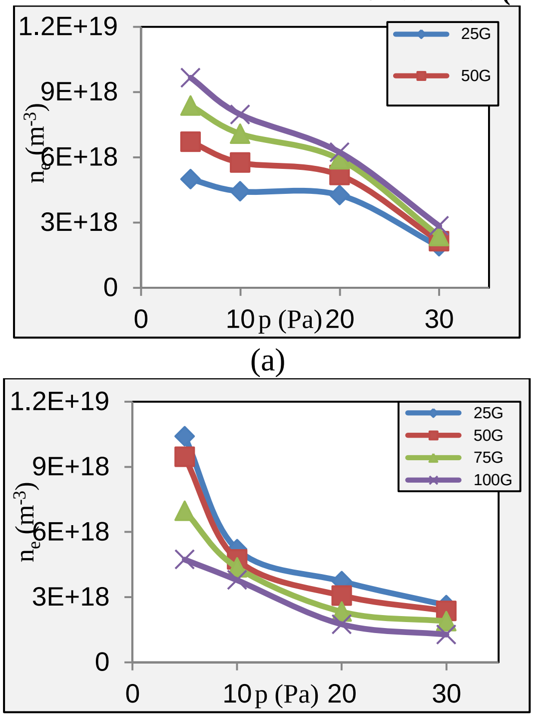


(b)

Fig.(5) Electron density variation as function of magnetic field at different pressures values in presence of (a) longitudinal magnetic field (b) transverse magnetic field.

4.2.2 Electron Density variation with pressure

Figures (6) demonstrate electron density variation with pressure for different values of magnetic field. The electron density decreases with increasing the pressure which it may be explained as follows: because the mean free path of electron at low pressure is longer than at high pressure, therefore the electron will gain more energy to ionize the gas atoms leading to increasing the electron density [10]. This effect is apparent in both cases of longitudinal and transverse magnetic fields. The results showed agreement with Eizaldeen F. Kotp *et.al*. [14] where they showed that the electron density decreases with increasing gas pressure.



(b)

Fig.(6): Electron density variation as function of pressure at different magnetic fields values in presence of (a) longitudinal magnetic field, (b) transverse magnetic field.

5. Conclusion

In presence of magnetic field, it was found that the electron temperature T_e and the electron density n_e decreased with increasing the pressure in both cases of longitudinal and transverse magnetic fields.

The electron temperature T_e decreased with increasing longitudinal magnetic field, but the electron temperature T_e increased in presence of transverse magnetic field.

It was found that the electron density n_e increased in presence of longitudinal magnetic field but the electron density n_e decreased with transversal magnetic field increasing.

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