The influence of an axial magnetic field on an abnormal glow discharge in Nitrogen at moderate pressures

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الخلاصة

يهدف البحث قياس بعض المتغيرات (مقاومة التفريغ وتوصيلها الكهربائي وكذلك درجة حرارة الإلكترون) لبلازما التفريغ الكهربائي فوق التوهج الاعتيادي المستمر عند قيم مختلفة من ضغط الغاز وتيارات التفريغ وتحت تأثير المجال المغناطيسي المحوري.وباستخدام طريقة المجس المزدوج. أظهرت النتائج إلى زيادة معدل تيار التفريغ ونقصان فرق الجهد المرافق بين المجسين ونتيجة لذلك فأن مقاومة التفريغ ودرجة حرارة الإلكترون تقل مع زيادة المجال المغناطيسي وتزداد التوصيلية الكهربائية ناتجاً من الاحتواء المغناطيسي للبلازما الذي يمنع انجراف الجسيمات المشحونة نحو جدران المنظومة. كذلك أظهرت النتائج توافقاً مقبولاً بالمقارنة مع نتائج البحوث المنشورة سابقاً.

ABSTRACT

In abnormal glow discharge under d.c. excitation at different pressure in a varying axial magnetic field in the range (0 to 6.5G) some measurements of plasma parameters, glow discharge resistance R_g electrical conductivity σ_g and electron temperature T_e have been carried out for various discharge currents using double probe method. The results show that the average discharge current increase and the corresponding voltage across the discharge gap decreased consequently glow discharge resistance and electron temperature decreased with the increasing magnetic field while the electrical conductivity increases according to that. This is due to magnetic field confinement which restricts expansion of the plasma charged practices. These measurements show a good agreement with the previous studies.

1. INTRODUCTION

When a magnetic field acts upon a glow and arc plasma, various changes such as an increase of equivalent pressure, a change of radial ion ,electron densities and marked change in the voltage current characteristics take place [1]. Theoretical and experimental work has been done in axial magnetic field by Allis and Allen [2], and Sen. [3].

The effect of a transverse magnetic field on the positive column of a glow discharge has been studied by Bechman [4]. The variation of current in a variable transverse magnetic field has studied by Sen. and Gupta [5]. As well as Sen. and Dash [6]. Observed voltage - current characteristics and showed that current gradually decreases and voltage across the arc increases with the increase of the magnetic field on the other hand, more experimental results for the axial electric field and the electron temperature of the positive column for the Helium, Neon and Argon in a transverse magnetic field are reviewed by Taro Kaneda [7].

Measurements show that the electron temperature and the axial electric field increase considerably with a transverse magnetic field in lower gas pressure. However, the influence of longitudinal magnetic field on breakdown potentials in dry air with plane parallel geometry have been investigated experimentally by Selvarajan and Natara Jan [8]. It was found that the magnetic field decreased the breakdown Potential at all the pressures studied. A Monte Carlo model was used by Jian-Jun Lin-Qiu [9], to describe the behavior of electrons and ions in an argon hollow – Cathode discharge under the influence of Transverse or Longitudinal magnetic field the model included Calculating the energy distribution of electrons and ions The result Show that the applied magnetic fields influence the characteristics of discharge in the negative glow more efficiently than that in the cathode dark space The effect of the magnetic field on the plasma parameters in the cathode fall region of the d.c-glow discharge has been studied by Hassouba [10].

It was observed that in the presence of the magnetic field, the electron temperature T_e are smaller than without magnetic field. While plasma density n_e increases a factor of two than without magnetic field. Recently، Krinberg [11] ،observed that when an external axial magnetic field is applied to a vacuum arc, the radial expansion of plasma from cathode spot transforms in to a plasma flow along the magnetic field ، provided that the electron- ion collision frequency smaller than the Lamor frequency ، As the magnetic field strength increases ، the diameter of the resulting cylindrical channel decreases ,this Leads to an increases in the electron temperature In the present work, the effect of an axial magnetic field on the abnormal glow discharge in nitrogen at moderate pressures, furthermore, plasma parameters، glow discharge resistance، electrical conductivity and electron temperatures were studied for different discharge currents using double probe method. Experimental results show that the average discharge current increases and the corresponding voltage across the positive column decreases، consequently both discharge resistance and electron temperature decreases with the increasing axial magnetic field while the electrical conductivity increases according to that, these results show a good agreement with the previous studies [12].

2. EXPERIMENTAL

The experimental system employed for the present study is shown in figure (1). The discharge tube was made from pyrex glass of radius(r=1.4 cm) and the distance between the electrodes is about(25 cm.) A hollow cylindrical cathode which was made from nickel material of (0.78 cm) in outer diameters and (2.8 cm) in length such shape of cathode may be served to avoid the formation of the striation. But the anode is taken as a circular disc of aluminum of diameter(1.6 cm).Both electrodes have been fixed in a vertical position with respect to the two-probe direction.

Floating double probe was made nearly at the mid point between the electrodes to measure the difference of floating potential between them as a function of discharge current. Both probe were constructed from 0.5 mm in diameter tungsten wire with 2 mm exposed beyond a glass sleeve, the probe has the same cylindrical shape and are identical. An external adjustment technique has been used to change the probe radial positions by means of magnetic effect on a cylindrical iron placed in the probe ports. The discharge tube was evacuated from air by rotary pump and the gas pressure was measured by ionization gauge.

The ballast resistor (10 kΩ) limited discharge current and keep the HV unit within its current capacity the floating potential difference between probe was measured as a function of discharge currents using digital avometer. A commercial nitrogen gas of 98% purity has been used in this work to produce plasma.

The experimental procedure was to apply the electrodes a steady (d.c) voltage from 6 Kv regulated power supply which was increased until a discharge current I_d of the order 2mA followed between the electrodes under an intermediate pressures nitrogen of (0.2 –5 torr). An external axial electrical magnetic field of order (0 - 6.5 Gauss) was also used to act upon the positive column of glow discharge.

3. RESULTS AND DISCUSSION

Two experiments were carried out in this work. One of them was the measurement of the plasma parameters (glow discharge resistance, electrical conductivity and electron temperature) under the action of axial magnetic field. The second experiment is carried out without axial magnetic field. In both experiments the discharge tube was cleaned by continuous discharge for a few hours. When the pressure was steady the discharge was then created.

3.1 Glow Discharge Resistance

Determination of the resistance of the column is straight forward, as both the current and the voltage across the column may be measured [13]. In the present study, the resistance R_g was determined from the voltage – current characteristics of glow discharge using ohm's law. Figure (2) represent glow discharge resistance as a function of gas pressure. It is appears from this figure that the relationship is nearly linear, i.e. R_g increases with the increasing gas pressure, this behavior can be attributed to the increasing number of non ionizing collisions between electrons and neutral particles. On the other hand the variation of R_g with the axial magnetic field at different pressure is inversely as shown in figure (3). Because the magnetic fields confine the plasma charged particles. This is in turn increase the charge carries, and in turn resistance decreases [14].

3.2 Electrical Conductivity

Electrical conductivity is a measure of how well a material accommodates the transport of the electric charge. According to Ohm's law the electrical conductivity is given by the ratio of the current density to the electric field strength [15].

$$\sigma = \frac{J}{E} = \frac{L}{RA} \quad \text{.....................} (1)$$

The electrical conductivity is one of the most important parameters governing the performance of an (MHD) power generator Nakamura, [16]. On the other hand the electrical conductivity of non ideal plasma is a fundamental quantity and it's measurement, therefore, of high interest to verify new theories Redmer, [17]. In this work the electrical conductivity has been obtained from the (I-E) characteristics using equation (1). Figure (4) shows electrical conductivity as a function of discharge current for different gas pressures. This curves show nearly a linear behavior because, the current and the discharge temperature increases according to the following equation [18].

$$I = 2\pi\, rL\, \sigma_s\, T^4 \quad \text{..........................} (2)$$

Where r and L are radius and length of the tube respectively, and σ_s is Steven's constant . Due to increasing temperature the degree of ionization will be increased according to the Suva equation [18]

$$\alpha = \frac{n_i}{n_n} \approx 2.4\times10^{15}\frac{T^{3/2}}{n_i}\exp(\frac{-ev_i}{KT}) \qquad .... (3)$$

Where n_i and n_n refer to the density of ionized and neutral particle respectively, vi is the ionization potential of gas and K is Boltzman's constant.

The high degree of ionization" means high density of charged particles" this in turn refer to a high electrical conductivity of discharge according to the following equation:

$$\sigma = en_e \mu_e \qquad .... (4)$$

Where μ_e is the electron mobility.

The electrical conductivity as a function of gas pressure is shown in figure (5). The behavior of the curve obtained show nearly exponential form. this can be explained that, the increasing pressure, will increase the number of non ionizing collisions, this decreasing the degree of ionization and consequently decreasing the electrical conductivity.

Another important result of this study, is the effect of the axial magnetic field on the glow discharge conductivity the relation between them is close to the linear behavior as illustrated from figure (6). This result is come from the magnetic confinement of plasma charged particles [14].

3.3 Electron Temperature:

Electron temperature is an important parameter in the positive column of a gas discharge. Once the electron temperature is known, a good estimate can be made of all other parameters of the positive column [20]. The electron temperature has been obtained from the relation between the average electron energy in (ev) and the reduced electric field E/P (KV $m^{-1}pa^{-1}$) as given by Meijer and Goedheer, [21].

$$<eu> = 5.3 + 43.9\,(E/P) \qquad .... (5)$$

$$<eu> = 3/2\, KT_e \qquad .... (6)$$

The reduced electric field was determined from measurements of the voltage between the two probes at the floating potential using a high–impedance ($10^6\Omega$) Voltmeters. This relation is a reasonable estimate for the electron temperature in the Townsend discharge and given values of T_e within the range in glow discharge. Figure (7) show the linear relation between T_e and E equation (5) at constant pressure. However, the inversible relation between T_e and pressure is shown in figure (8). Because the increasing pressure will decreases the mean free path of electron λ_e. Therefore the electron lost almost its energy during collision with other plasma particles. In other word, if the pressure is decreased, the loss of plasma due to diffusion or free–fall increase and consequently the electron temperature must be raised to sustain the generation of the plasma [22]

3. 3.1. Magnetic Effect on the electron Temperature

The particles in the plasma، in the presence of a magnetic field are characterized by two different temperature one representing the translation of the particle parallel to the magnetic field $T_{//}$ and the second representing the translation perpendicular to the magnetic field $T_{\perp}$. These are caused by the fact that the force acting on the species parallel to the magnetic field are different from those acting perpendicular to it [22]. In the present work، the results Show that the axial magnetic field reduce the motion of charged particles toward the wall (perpendicular motion) therefore decreasing the electron temperature and increasing the equivalent plasma pressure (plasma pressures plus magnetic pressure) [1] .The variation of both σ_g and T_e with the magnetic field as shown in figure (9).

4-CONCLUSIONS

In the present work, a medium pressure glow discharge have been investigated over a wide range of operating conditions (tube diameter, pressure and external parameter of axial magnetic field). Thus complete investigation had yield several important results.

1. The axial magnetic field increases the average discharge current and decreases the corresponding voltage across the positive column, this in turn decreases the glow discharge resistance and increases its electrical conductivity, this is due to a magnetic field confinement.
2. The electron temperature decreases with increasing axial magnetic field.
3. Another remarkable conclusion, is that both electron temperature and electrical conductivity, inversely proportional to the gas pressure and the relation between them obey approximately the decreasing exponential function.
4. The possibility of using the relation between the average electron energy and the reduced electric field, which is a reasonable estimated for the electron temperature in the Townsend discharge and given acceptable values of T_e within the range in glow discharge.

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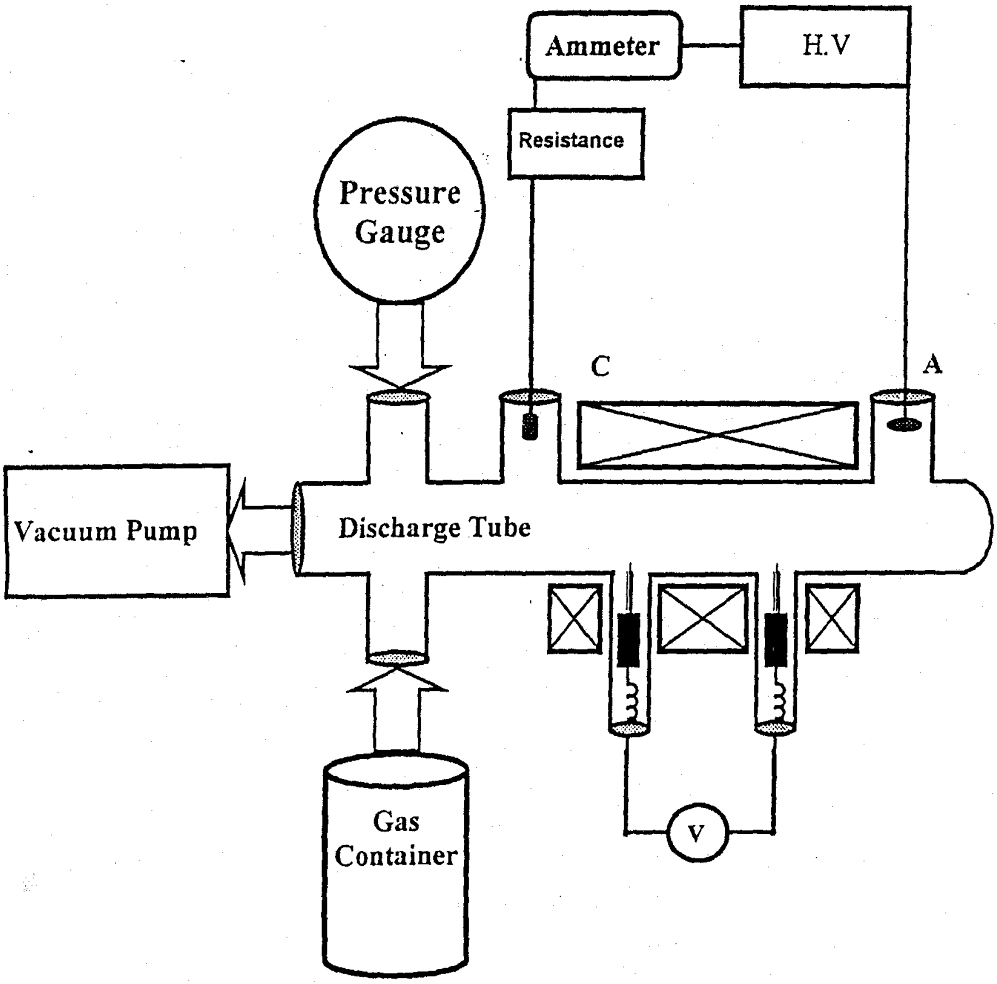
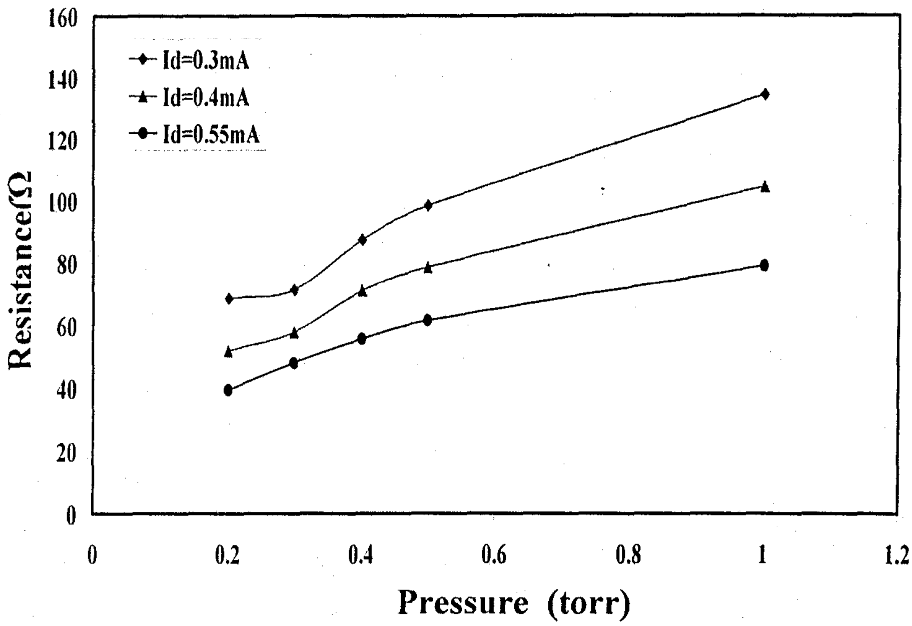
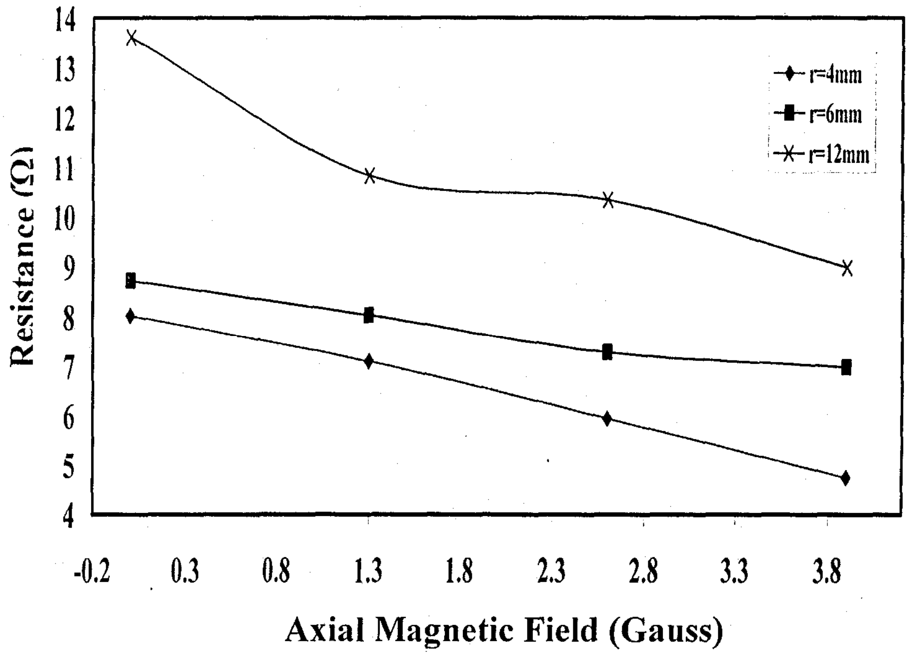


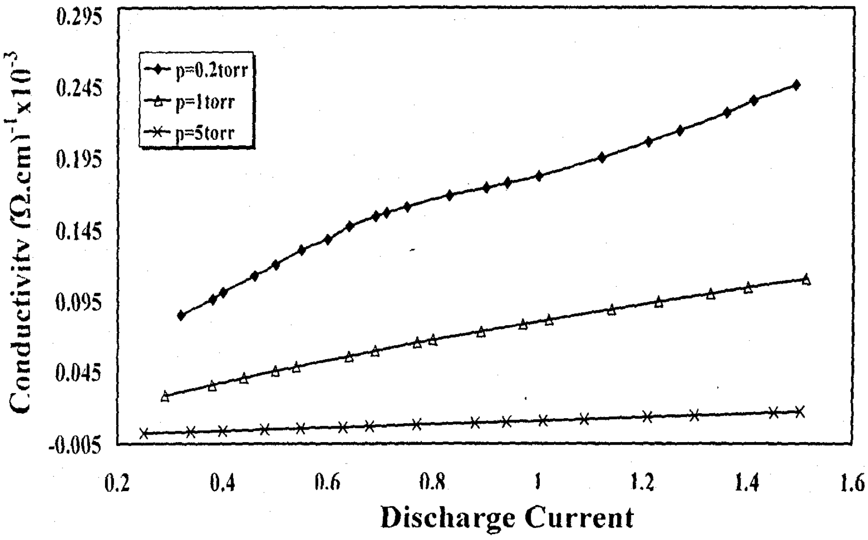
Fig(1): Electric Glow Discharge System



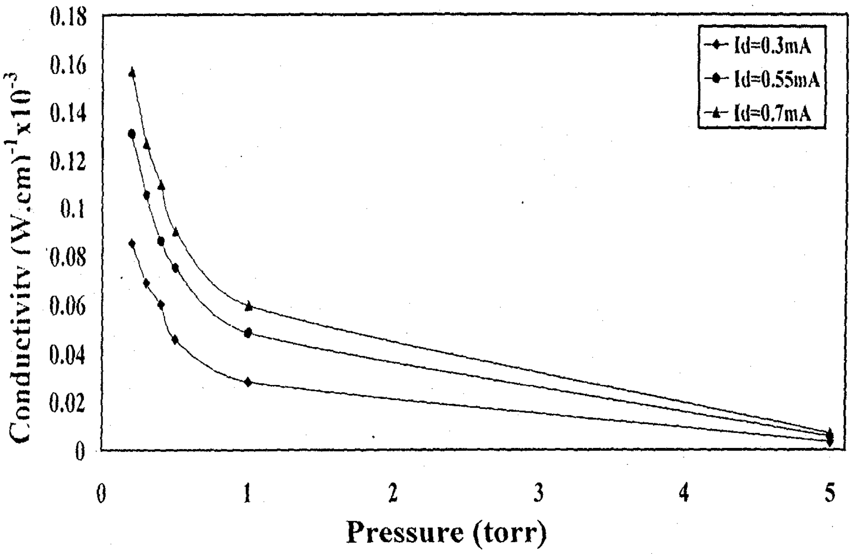
Figure(2)Glow Discharge Resistance as a Function of Pressure for Different Discharge Currents



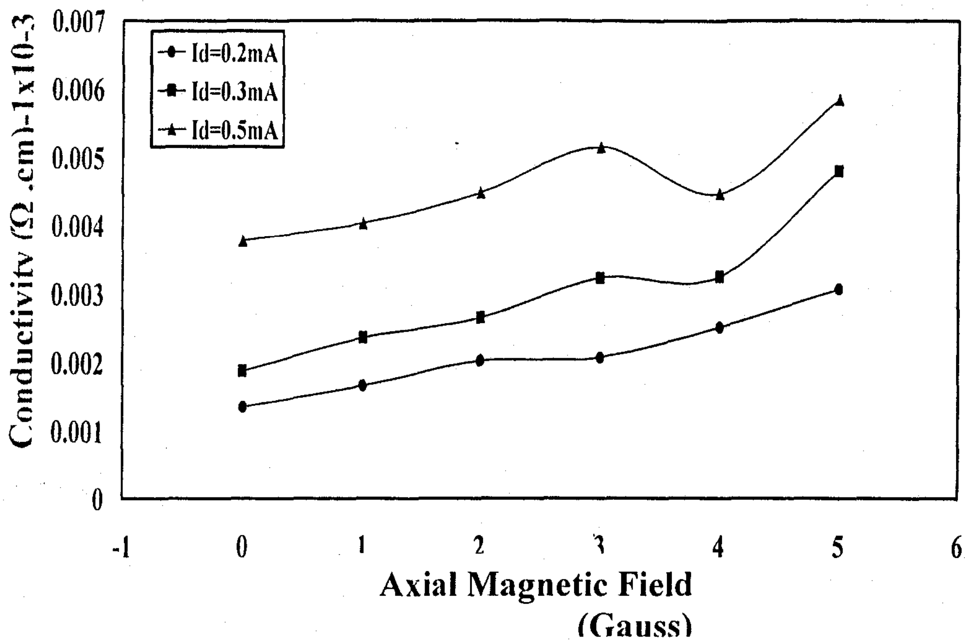
Figure(3) Glow Discharge Resistance as a Function of an Axial Magnetic Field for different positions



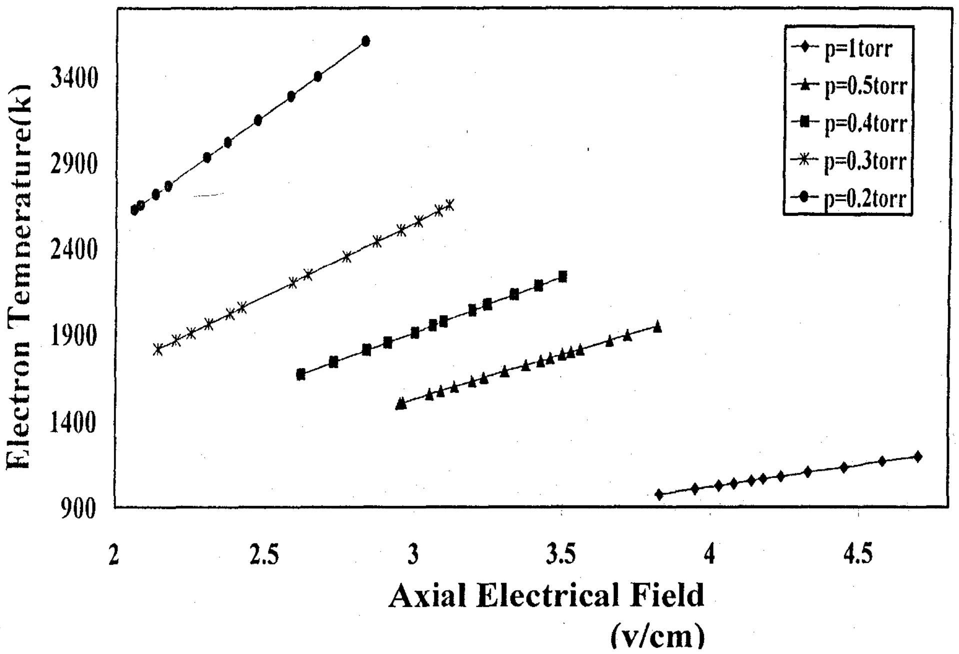
Figure(4)Electrical Conductivity as a Function of Discharge Currents for Different Gas Pressures



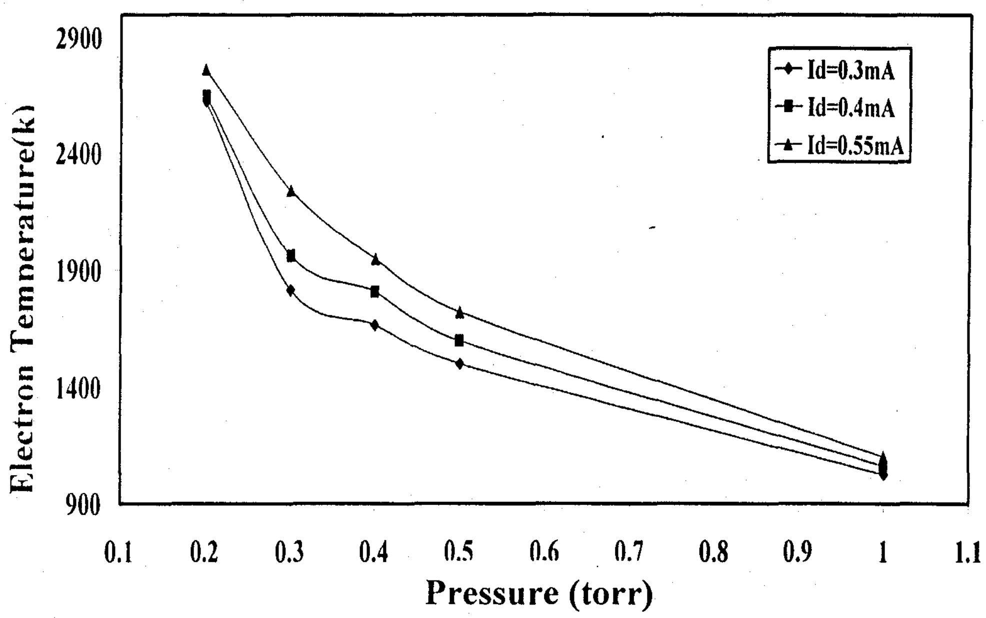
Figure(5)Electrical Conductivity as a Function of Pressure for Different Discharge Current



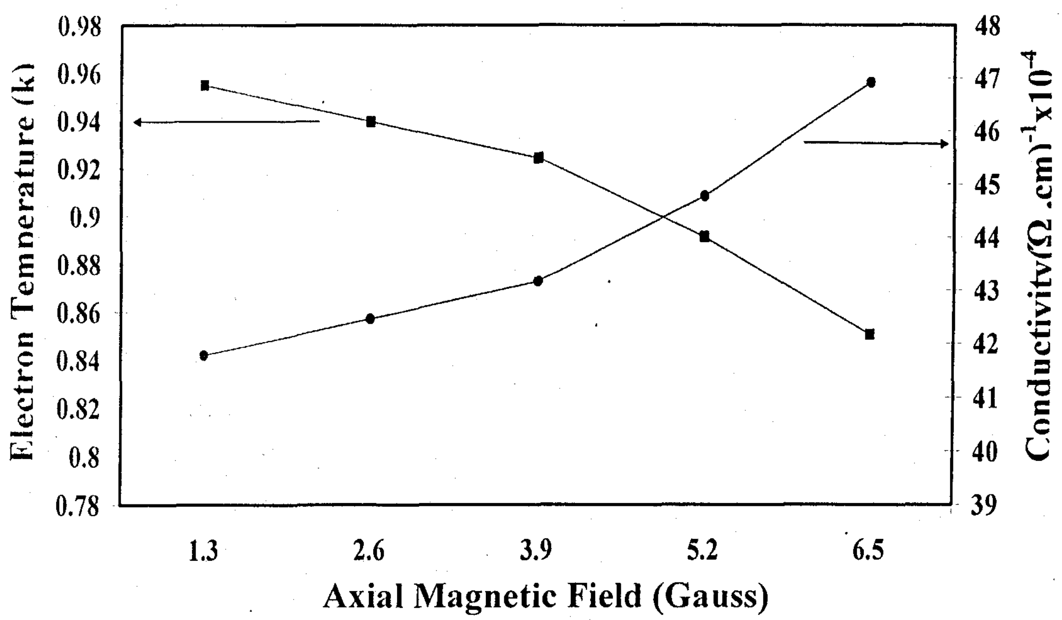
Figure(6)Electrical Conductivity as a Function of an Axial Magnetic Field for Different Discharge Currents



Figure(7)Electron Temperature as a Function of an Axial Electrical Field for Different Gas Pressures



Figure(8)Electron Temperature as a Function of Pressure for Different Discharge Currents



Figure(9)Electron Temperature and Electrical Conductivity as a Function of an Axial Magnetic Field