Variation of Discharge Current with a Transverse Magnetic Field in Rectangular Discharge Tube for Molecular Gases

Qais Thanon Najim Algwari — *College of Electronics Eng.*
Saffaa Aldeen A. S. Al-Taie — *College of Basic Education*
University of Mosul

Received: 19 / 11 / 2006 ; Accepted: 9 / 1 / 2007

Abstract:

The variation of discharge current with a transverse magnetic fields (0-150 Gauss) has been studied in the positive column of glow discharge in N_2 and CO_2 with the pressures range from (0.75 to 7.5 torrs). It is found that the current gradually rises with the increase of magnetic field, and then attains a maximum value at particular value of the magnetic field which is the same for all the two gases. It was found that this value is independent of the pressure for the initial discharge current, and then gradually decreases.

تغير تيار التفريغ مع المجال المغناطيسي المستعرض في أنبوب التفريغ المستطيل للغازات الجزيئية

قيس ذنون نجم الجواري — *كلية هندسة الالكترونيات*
صفاء الدين عبد الله سليمان الطائي — *كلية التربية الأساسية*
جامعة الموصل

ملخص البحث :

تم دراسة تّغير تيار التفريغ عبر المجالات المغناطيسية المستعرضة (٠-١٥٠ كاوس) في العمود الموجب للتفريغ ألتوهجي لغازي N_2 و CO_2 في مدى الضغوط من (٠.٧٥الى ٧.٥ تور). وقد وجد بان التيار يزداد بصورة تدريجية مع زيادة المجال المغناطيسي إلى أن يبلغ قيمة عظمى عند قيمة محددة من المجال المغناطيسي لكلا الغازين ولا تعتمد على قيمة الضغط لنفس التيار.

Introduction:

When a magnetic field acts upon a glow discharge, various changes such as increase of equivalent pressure, decrease in the length of the cathode dark space and marked changes in the voltage – current characteristics of discharge take place [Kaneda[1], 1978]. Theoretical analysis of these phenomena has been provided by Townsend (1938) [Von Engle, 1965]. The effect of transverse magnetic field on the V-I characteristics curve in a conventional discharge tube has been studied by [Kaneda[2], 1978]. Discharge characteristics for rectangular tube has been studied by many research groups [Kaneda, et al., 1984, Chang, et al., 1979 and Altaie, 2005]. Several reports outlining the variation of discharge current with transverse magnetic field in cylindrical tube [Sen and Gupta, 1971] and coaxial discharge tube [Najim, 1997]. The object of the present investigations is thus to study the variation of discharge current in a variable magnetic field in a rectangular discharge tube, at different values of gas pressure.

Experimental Arrangement:

A dc source from a (3 KV) regulated power supply, type Lybold, was used to ionize the gases. The discharge tube was rectangular of a length (45 mm), with profile of the positive column (40×25 mm), and fitted with two circular electrodes as shown in figure (1). The electrodes were made from stainless steel of diameter (15 mm). A carbon dioxide and nitrogen gas used with a purity 99.95%.

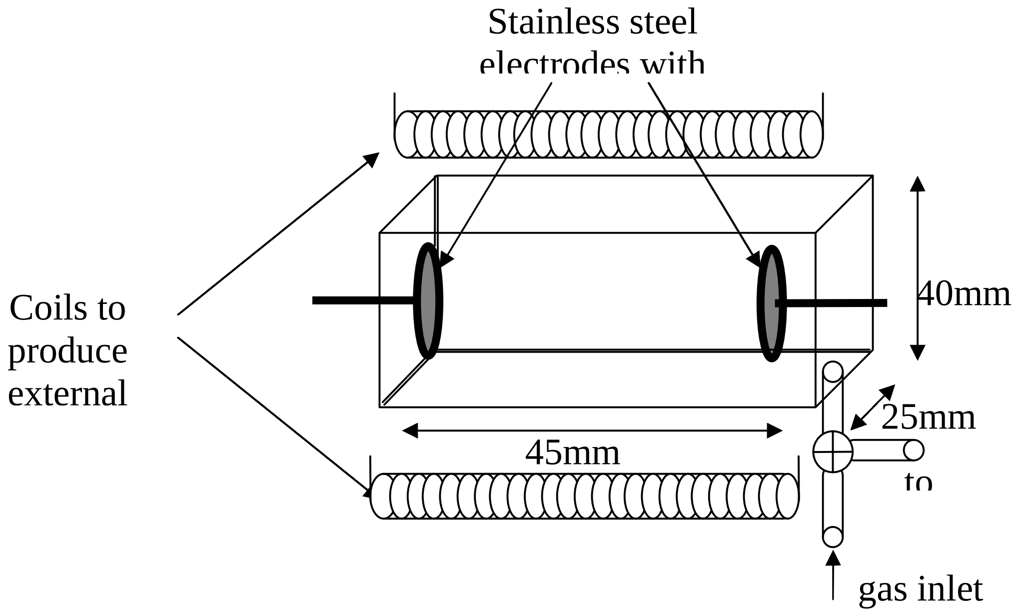

Fig. (1) : The schematic diagram of the discharge tube.

The magnetic field was provided by a coil of copper with 200 turns and extreme care was taken to ensure that the lines of the force were perpendicular to the axis of the discharge tube. The magnetic field, various from (0 to 150) Gauss, controlled by the amount of current pass through the coil.

By keeping the pressure of the gas constant at a particular value, the magnetic field was varied and the dc discharge current between the two electrodes was measured using digital multimeter. The same procedure was repeated for different values of the pressure from (0.75 up to 7.5) torr and for different values of initial discharge current.

Results :

The variation of the discharge current with the magnetic field, for different initial discharge current, (I_o=0.2, 0.3 and 0.4) mA, has been plotted for N_2 and CO_2 in figures (2, 3, 4, 5, 6, 7 and 8) respectively.

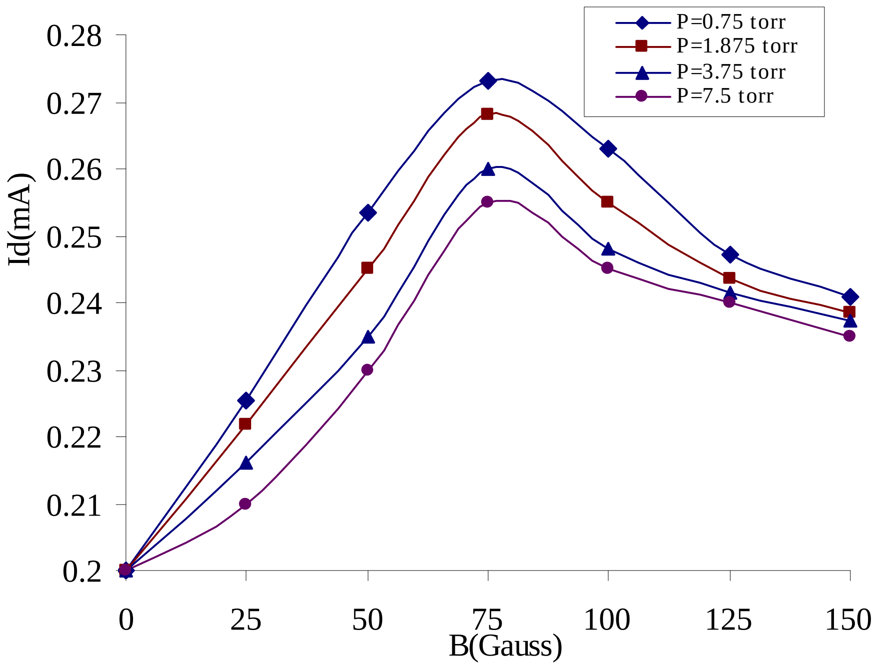

Fig. (2):Variation of discharge current with magnetic field for different pressures of N_2 (I_d=0.2mA)

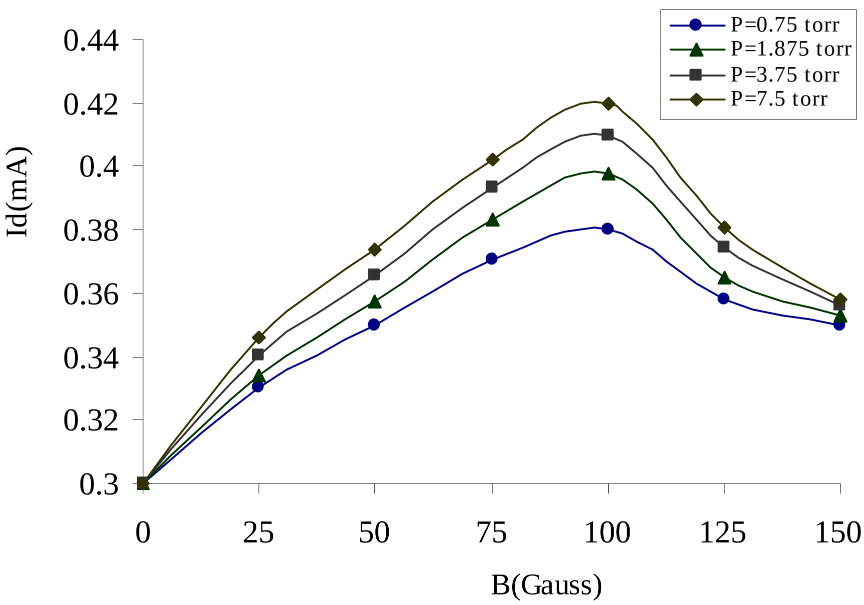

Fig.(3):Variation of discharge current with magnetic field for different pressures of N_2 (I_d=0.3mA)

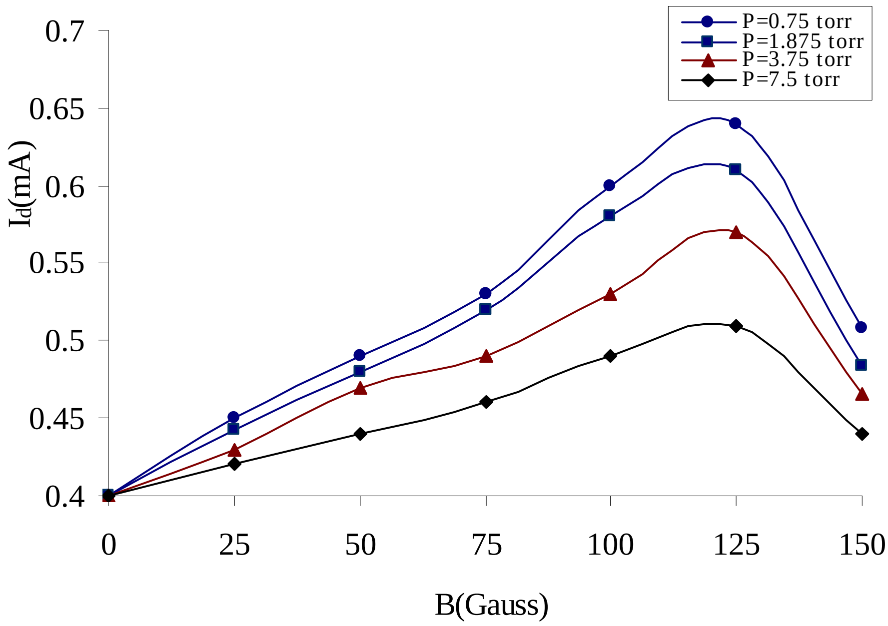

Fig. (4):Variation of discharge current with magnetic field for different pressures of N_2 (I_d=0.4mA)

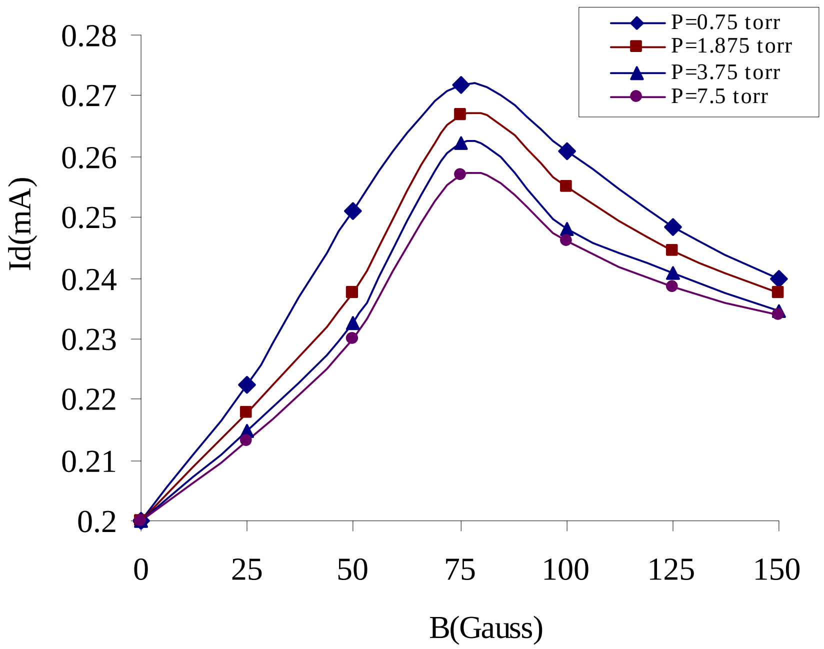

Fig. (5):Variation of discharge current with magnetic field for different pressures of CO_2 (I_d=0.2mA)

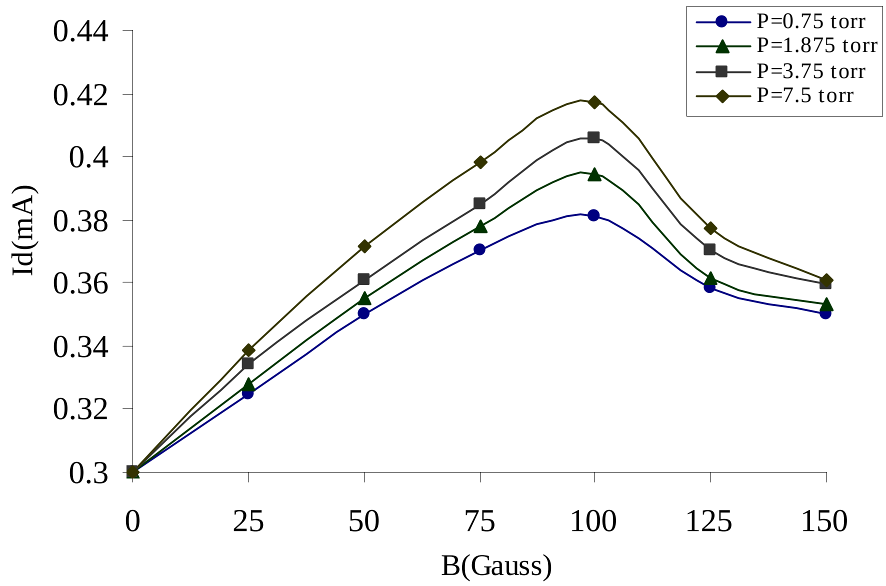

Fig. (6):Variation of discharge current with magnetic field for different pressures of CO_2 (I_d=0.3mA)

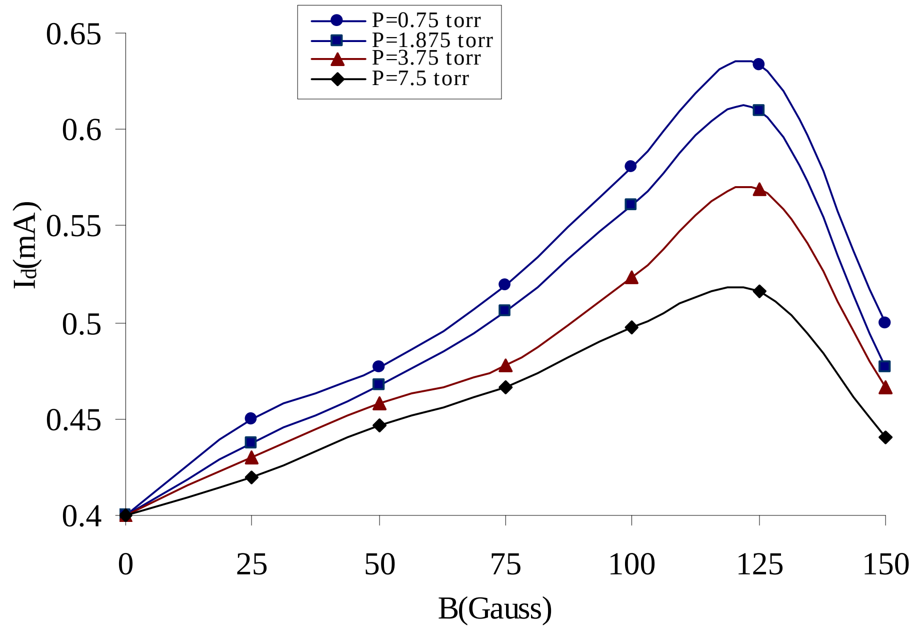

Fig. (7): Variation of discharge current with magnetic field for different pressures of CO_2 (I_d=0.4mA)

The nature of the curves are the same for two gases showing a gradual rise of discharge current with the magnetic field, attaining a maximum value at particular value of the magnetic field and gradually decreasing. Furthermore, it is evident that the value of magnetic at which the discharge current becomes a maximum is the same for all the range of gas pressure provided that the initial discharge current. It was seen in these figures that the value of magnetic field at which the discharge reaches its maximum value increases with increasing the value of initial discharge current.

The values of I_{max}, the maximum value of current, depend upon pressure. The experimental results give an indication that the values of ($I_{max}P$) are almost constant for the same initial current.

Discussions and Conclusions:

When a transverse magnetic field acts on plasma two effects are observed. The first one, the magnetic field push the electrons and ions from the axis of the plasma to the wall, thereby increasing the loss of electrons and ions. As a result of that, to compensate for this loss, the axial electric fields will increases thus increasing the ionization and the electron temperature (Backman, 1948) ,see [Sen and Gupta, 1971]. The electric axial field increases from E to $E(\alpha+\beta^2/\alpha)^{1/2}$ where α and β are given by the following terms:

$$\alpha = 1 - h^2 + h^4 \exp(h^2) \int_h^\infty \frac{\exp(-h)}{h} dh \qquad \cdots(1)$$

$$\beta = \frac{1}{2} h\sqrt{\pi} \left[1 - 2h^2 + 4h^3 \exp(h^2) \int_h^\infty \exp(-h^2) dh \right] \qquad \cdots(2)$$

$$h = \frac{eH\lambda}{m\omega} \qquad \cdots(3)$$

where H is the magnetic field, λ the electronic mean free path and ω is the most probable electronic speed which is given by:

$$\omega = \sqrt{\frac{2KT_e}{m}} \qquad \cdots(4)$$

where T_e is the electron temperature and K is Boltzmann constant. Since the electron velocity distribution is Maxwellian. Therefore the expression in equation (3) can be reduced to simplified form as:

$$h = \frac{2eHL}{mP v_r \sqrt{\pi}} \qquad \cdots(5)$$

where v_r is the random velocity and L is the mean free path of an electron in the gas at a pressure of 1 torr; and h is a very small quantity, then:

$$\beta = \frac{1}{2} h \sqrt{\pi} = \frac{eHL}{mP v_r} \qquad \cdots(6)$$

$$and \quad \alpha \approx 1$$

then

$$E_H = E\left(1+\beta^2\right)^{1/2} = E\left(1+C_1 \frac{H^2}{P^2}\right)^{1/2} \qquad \cdots(7)$$

where C_1 is a constant for a particular gas and is given by $C_1=[eL/mv_r]^2$. It is clear from this equation that as the transverse magnetic field increase the axial electric field will also increase. This has been verified experimentally by Beckman for H_2, N_2, He and Ne gases [Sen and Gupta, 1971]. We have found that the above expression can be used as representing the increase of the axial electric field with the increase of the transverse magnetic field.

The increase of the axial electric field in the presence of a transverse magnetic field can not be adequately represented the factor $[1+C_1(H^2/P^2)]^{1/2}$ as has been shown also by Beckman and, as in the case of the equivalent pressure concept, the equation has a limited applicability within a certain of *(H/P)* values.

The second effect is the electrons are moving with the same velocity and exhibit distribution is Maxwellian; while this is true in the case of molecular gases [Sen and Gupta, 1971]. It can thus concluded that the variation of current in the discharge in the presence of a transverse magnetic field is a function of the radial electron density and the axial electric field, which are themselves functions of the transverse magnetic field.

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