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Measurements of Some Plasma Parameters of Hybrid Discharge in Air at Moderate Pressure

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الخلاصة

يتضمن البحث قياس بعض معلمات بلازما (المجال الكهربائي المحوري والقطري ، التوصيلية الكهربائية للعمود الموجب وللتفريغ الكهربائي بين الأقطاب) التفريغ ألتوهجي تحت تأثير المجال الكهربائي الراديوي (التفريغ الهجين) لمختلف ضغوط الغاز وتيارات التفريغ الكهربائي باستخدام طريقة المجس المزدوج . أظهرت النتائج أن التوزيع القطري لكل من المجال الكهربائي المحوري والقطري المقاس بين المجسين يتبع دالة آسية تزايدية ويزداد المجال بزيادة سعة المجال الكهربائي الراديوي وبدورها تتناقص التوصيلية الكهربائية للعمود الموجب. كما أن المجال الكهربائي المحوري المقاس بين الأقطاب يتناقص مع كلاً من التردد وسعة المجال الراديوي مؤدياً ذلك إلى زيادة التوصيلية الكهربائية بين الأقطاب.إضافة إلى أن التوصيلية تتناسب طردياً مع الضغط في حين أن توصيلية العمود الموجب تتناسب عكسياً مع الضغط.

ABSTRACT

In abnormal glow discharge in air under (D.C) excitation at different pressures in varying both frequency and amplitude of radio frequency field. Measurements of some plasma parameters such as (axial and radial electric field, electrical conductivity of positive column and electrical conductivity of glow discharge between the electrodes) have been reported for various currents discharge by using double probe method. The results show that the radial distribution of both axial and radial electric field measured between probes is nearly exponential and increases with the increasing A.C amplitude. This will in turn the conductivity of the positive column decreasing, furthermore to that he variation of axial electric field between electrodes with both frequency and A.C amplitude is nearly inversible leading to increasing electrical conductivity between electrodes according to that. The electrical conductivity between electrodes proportional linearly with the gas pressure, while the electrical conductivity of the positive column proportional inversely with gas pressure.

INTRODUCTION

Several methods have been developed for stabilizing volume discharges. One is to impose a strong (R.F)field on the positive column of the D.C discharge, in the direction transverse with respect to the constant field [1].The frequency at which a high frequency discharge is excited has considerable influence on the properties of the plasma [2]. The effect of driving frequency (13.56-50MHz) on the electrical characteristics And the optical properties of hydrogen discharge has been studied under constant power conditions [3]. As frequency is increased, the R.F voltage required for maintaining a constant power level is reduced, while the discharge current increases and the impedance decreases. Furthermore analysis of these measurements through theoretical model reveal that the frequency influences the motion of charged species as well as the electron energy and the electric field, resulting in a modification of their spatial distribution. moreover, the loss rate of charged species is reduced, leading to an increase of the plasma density and to decrease the electric field. Similarities and differences between direct current and radio-frequency glow discharges have been shown [4].the result for the dc and the R.F discharges have been compared. It is found that for the same input power and pressure, the R.F discharge require lower voltage than the D.C discharge. This is due to the more efficient ionization in the R.F mode. Tolunay [5] has investigated the effect of R.F power density on the dark conductivity activation energy, deposition rate and photoconductivity of a set of S1:H films, which were prepared by glow discharge deposition of silane sih4 gas in a capacitively-Coupled R.F plasma reactor. It was observed that both dark conductivity and photo conductivity increases with increasing R.F power density. Recently there is increasing interest in exploring the use of plasma actuator for active flow control in aero space application due to several advantage [6]. The focus of this effort is on methods that utilize radio frequency (R.F) or low frequency methods which have seen increasing popularity in recent time R.F excitation is utilized not only as a mechanism to ionize flow volume, but also for control itself.

The present work attempts to clarify the effect of both frequency and A.C-amplitude of (R.F) source, on both axial and radial electric field, as well as on both electrical conductivity of(positive column and the discharge between electrodes),of an abnormal glow discharge in air at moderate pressures. The results reveal that the radial distribution of both axial and radial electric field measured between the probes increases with increasing A.C-amplitude.

EXPERIMENTAL

In the present work a number experiments were performed to study the influence of both frequency and A.C- amplitude of (R.F) output on a characteristic of (D.C) glow discharge in air at moderate pressure.

The First Discharge System

In the first set up [7], a Pyrex glass cylinder of distance 2cm between electrodes have been used as the discharge tube. Electrodes are made from tungsten rod of diameter 1.5 mm, one electrode is placed at the extremities of the discharge cell and the other is fixed vertically. the discharge is created when these electrodes are biased by regulated (D.C) voltage. Also the discharge cell is inductively coupled to (R.F) generator. To study the behavior of glow discharge under the action of (R.F), the discharge is placed within an excitor coil that is traversed by a high frequency current. The average diameter of the excitation coil is 6cm and the number of turns of the coil is 50. The excitation frequency ranged from (600kHz to 1MHz). the output voltage across the coil up to 1500V peak to peak and (R.F)power available is 40W. the discharge cell is then evacuated from air to medium pressures (0.2-1torr) by using mechanical pump. This pressure is controlled by a precision thermocouple gauge. The schematic representation of the first discharge system is shown in figure (1). This system was used to study the effect of (R.F) power on the axial electric field between the electrodes of glow discharge and its electrical conductivity.

The Second Discharge System

In the second discharge system attempt have been carried out to investigate the effect of (R.F) power on both axial and radial electric field of the positive column of glow discharge and its electrical conductivity, the first discharge system was developed to include the double probe method for measuring the axial electric field from double probe characteristics In the second set of experiments the discharge tube was a pyrex glass of radius (r=1.4cm) and the distance between the electrodes is adjusted to about 25cm. A hollow cylindrical cathode is made from nickel material of (0.78cm) in outer diameter and (2.8cm) in length such shape of cathode may be served to avoid the formation of the striation. The anode is a circular disk made of aluminum of (1.6cm) in diameter. Both electrodes are fixed in a vertical position with respect to the two probe direction. Floating double probe measurements were made nearly at the mid point between the two electrodes for both the axial and radial electric field from the double probe characteristic. both probes are made from tungsten wire of diameter (0.33mm) with (1.75mm) exposed beyond a glass sleeve. An external adjustment technique has been used to change the probe radial position by means of a magnetic effect on a cylindrical iron placed in the probe ports. A chain of ten (20kΩ) standard resistors immersed in oil for cooling were inserted in the circuit served as stabilization resistors of glow discharge. The electrical set up used in this study is shown in figure (2).

RESULTS AND DISCUSSIONS

The measurements are preformed for experimental conditions such as used by AL-Hakary (7), in a hybrid glow discharge in air. The discharge conditions measured in this study where the gas pressure was ranged from (0.2 to 1torr), the frequency ranged between (600KH and 1MHz), output voltage up to (1500V) and an electrical power of about (40W) both for the (D.C) and the (R.F) source.

Axial Electrical Field

The axial electric field has been measured in a two regions of the glow discharge. The first has been measured between the electrodes i.e (total discharge) under different frequencies and A.C-amplitude of (R.F) source. Figures (3and4), show the relation between axial electric field and frequency as well as A.C-amplitude of (R.F) source for different discharge currents. This is due to the(R.F) discharge require lower voltage than the (D.C) discharge, this in turn due to the more efficient ionization in the (R.F) mode. Moreover the Loss rate of charged species is reduced, Leading to an increases of plasma density and to decrease the axial electric field [3and4]

On the other hand the axial electric field is measured across the positive column by using double probe characteristics from the displacement of the characteristics on the x-axis which is represent probe voltage. Figures (5and 6), represent the pressure dependence of axial electric field for different frequencies and A.C-amplitude of (R.F) source. Both figures show nearly same behavior (i.e). Increasing pressure will decreases the mean free path of electron due to increasing the number of collision, finally increasing the glow discharge resistance; consequently the electric field will be increased [5]. However the effect of frequency is to decreases the electric field [3and4]. Contrary to this effect, the A.C-amplitude is to increases the electric because the probability of collision of electron with other plasma particles will be increased with increasing A.C-amplitude, since ions created near anode can reach the cathode before the field is reversed. In this situation, the distance traveled by the ions in the electric field becomes larger than the thickness of the plasma sheath [6and7]. The reduced electric field (E\p) versus gas pressures shown in figure (7). This figure seem to be in a good agreement with other previous studies [8 and 9].

Radial Distributions of Both Axial An Radial Electric Field

Several authors have reported theoretical studies concerning the radial distributions of electric field strength in the cylindrical positive column of direct current discharge [10and11]. These authors assumed a Maxwellian distribution of the random energy of the ions and electrons with constant ions and electron temperature. In this work, both the axial and radial electric field are measured from the double probe characteristics and using the relation [12].

$$E_r = - \frac{KTe}{e}\frac{1}{ne}\frac{dne}{dr} \text{.................}(1)$$

Where T_e and n_e are the temperature and density of electron respectively which obtained from previous studies [7and13]. Figures [8and9] show the nearly increasing exponential relation for both axial and radial electric field. This dependence is due to hollow-cathode discharge, in this case all of the energy of the fast primary electron emitted from the cathode is expended on the excitation and ionization of the working gas within a distance of several centimeters from the cathode and , the gas at the system axial ionized mainly by the electrons will diffuse from the regions where the plasma has already been produced [11]. Therefore the plasma density and its electrical conductivity will be higher at the center of discharge. This means that the electric field is minimum at the center. The behavior of electric field is a reasonable agreement compared with other studies [10&11].

The Electrical Conductivity

Electrical conductivity is a measure of how well a material accommodates the transport of electric charge. According to ohm's law the ratio of the current density to the electric field strength represent electrical conductivity:

$$\sigma = \frac{J}{E} = \frac{L}{RA} \text{............} (2)$$

Where R is the resistance of glow discharge of length Land cross section area A. The electrical conductivity is one of the most important parameters governing the performance of a magneto hydro dynamic (MHD) power generator [14]. As well as the electrical conductivity of non ideal plasma is a fundamental quantity and it's measurement, therefore , of high interest to verify new theories [15]. The electrical conductivity has been obtained in a two regions of the plasma; first region represent the conductivity of total discharge at different frequency and A.C-amplitude of (R.F) field. Figures (10and11) illustrated the nearly linear increasing relation of electrical conductivity versus frequency and A.C-amplitude of (R.F) source. This effect is attributed to the same previous reasons [3and4] The second region , represents the electrical conductivity of the positive column which is increase with creasing frequency as shown in figure (12). The effect of frequency upon the electric field is explained in section (3.1).

Pressure Dependence of Conductivity

The most important result of the present study is the pressure dependence of electrical conductivity. Because there are two different behaviors of conductivity variation with the pressure. In other word, the positive electrical conductivity decreases exponentially with increasing gas pressure figures (12and13). However, the discharge electrical conductivity increases nearly linearly with increasing gas pressure figure (14). This phenomena (increasing the discharge electrical conductivity and decreasing the positive electrical conductivity with gas pressure) this attributed to the main effects of an increase in pressure on a normal glow discharge are contraction of the length of the cathode region, a marked increase in the current density there, and usually, an increase in the voltage gradient in the positive column [16].

CONCLUSIONS

In the present paper we have provided a review of excitation frequency and A.C-amplitude effects in plasma processes of glow discharge in air at medium pressure. Theoretical modeling predicts that frequency has a strong influence on the plasma parameters. We presented experimental evidence which confirms the theoretical predictions that (R.F) plasma are generally more efficient than their DC plasma, this in turn leading to increasing the plasma electrical conductivity due to increasing the number of ionizing collision. As well as4 the discharge electrical conductivity can be enhanced by increasing the gas pressure and causing contraction the length of space charge regions. Finally the radial distribution of both axial and radial electric field are nearly increasing exponential and show a reasonable agreement with the previous studies.

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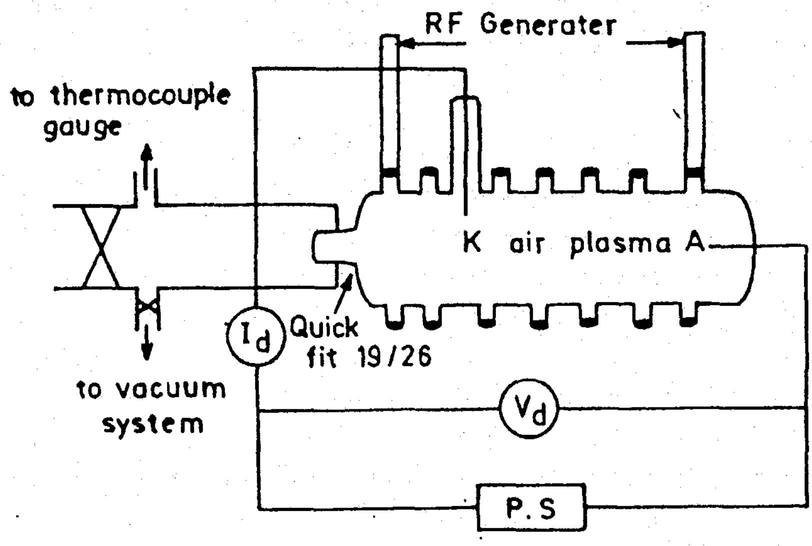
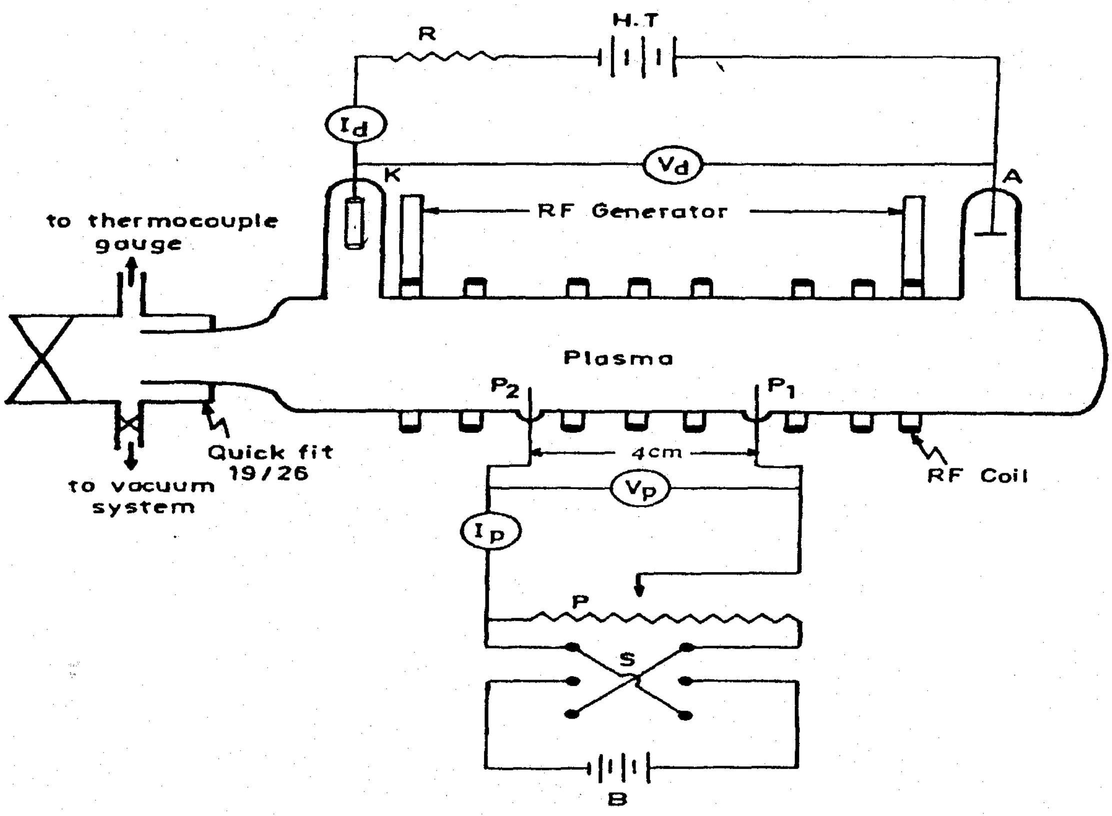
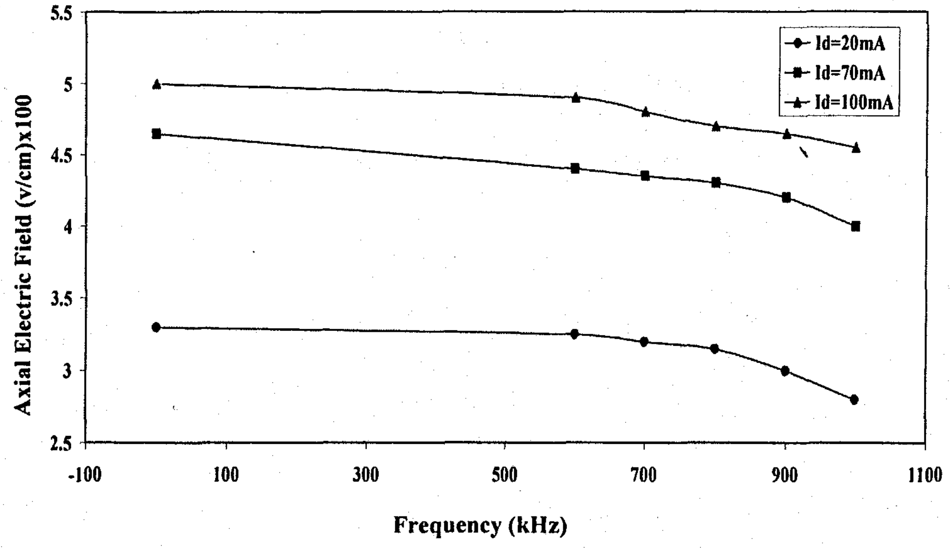


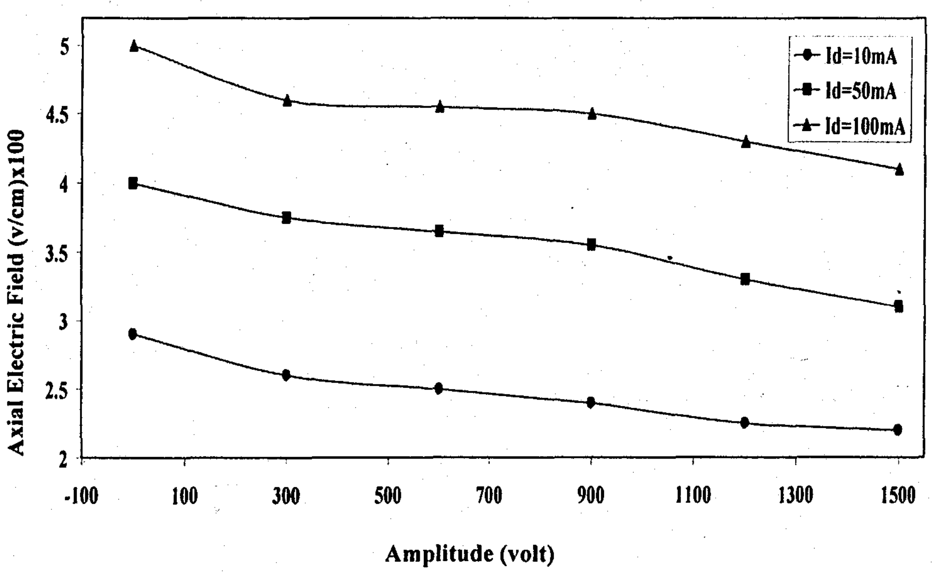
Fig(1) Experimental Setup of the First Discharge System



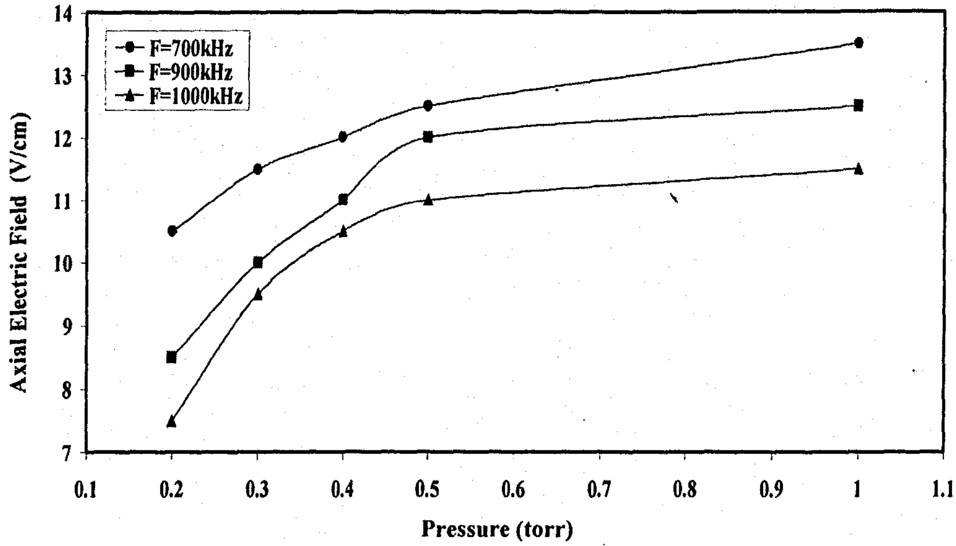
Fig(2) Experimental Setup of the Second Discharge System



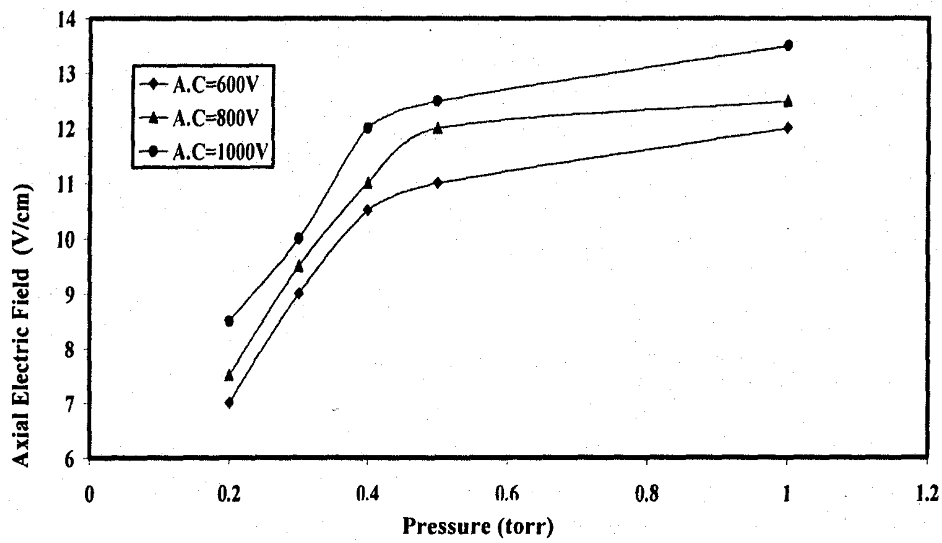
Fig(3):Axial Electric Field as a Function of Frequency for Different Discharge Currents



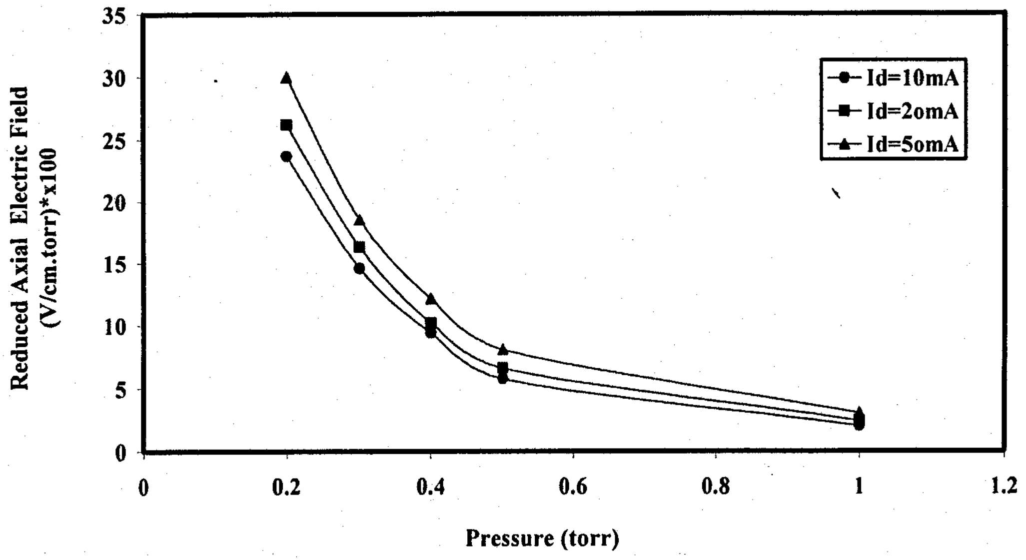
Fig(4):Axial Electric Field as a Function of A.C - Amplitude for Different Discharge Currents



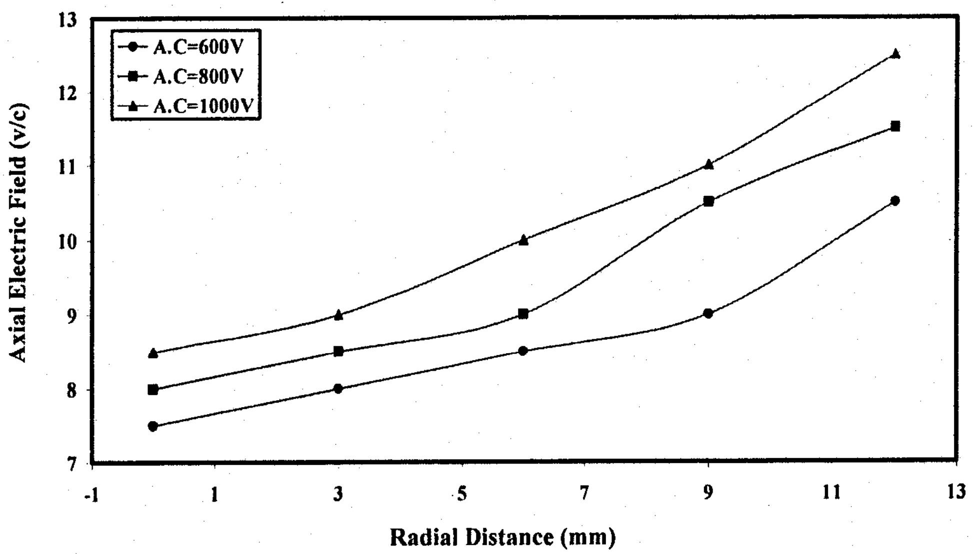
Fig(5):Axial Electric Field as a Function of Gas Pressure for Different Frequency



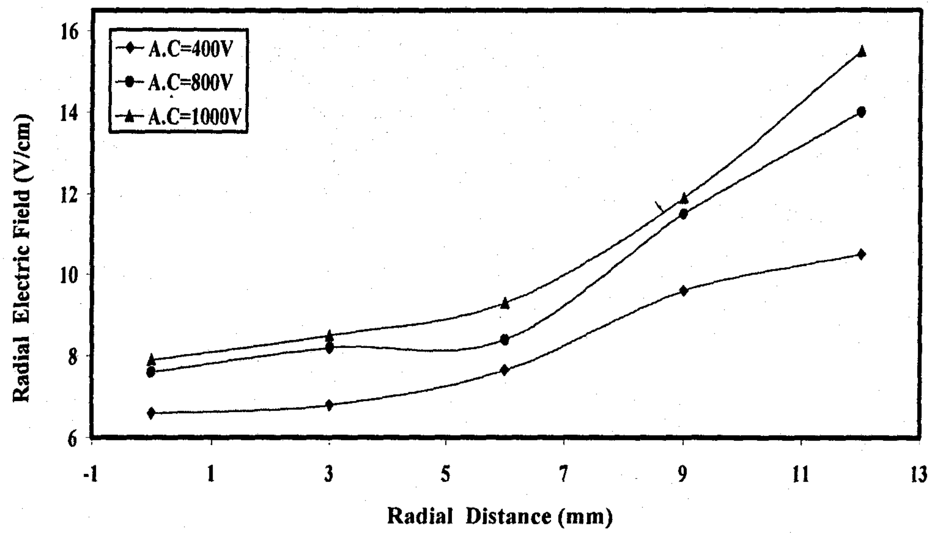
Fig(6):Axial Electric Field as a Function of Gas Pressure for Different A.C- Amplitude



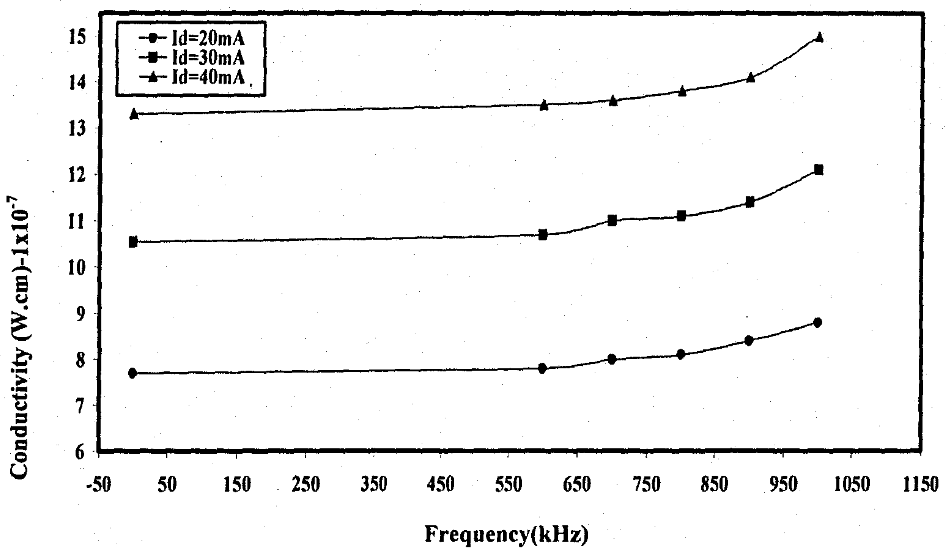
Fig(7):Variation of Reduced Axial Electric Field with Gas Pressure for Different Discharge Currents



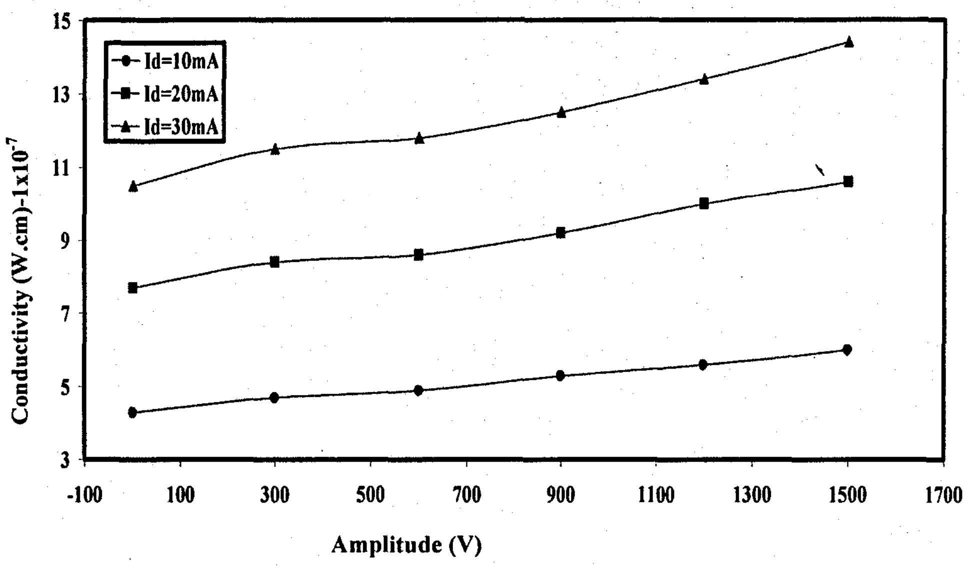
Fig(8):Radial Distribution of Axial Electric Field for Different A.C- Amplitude



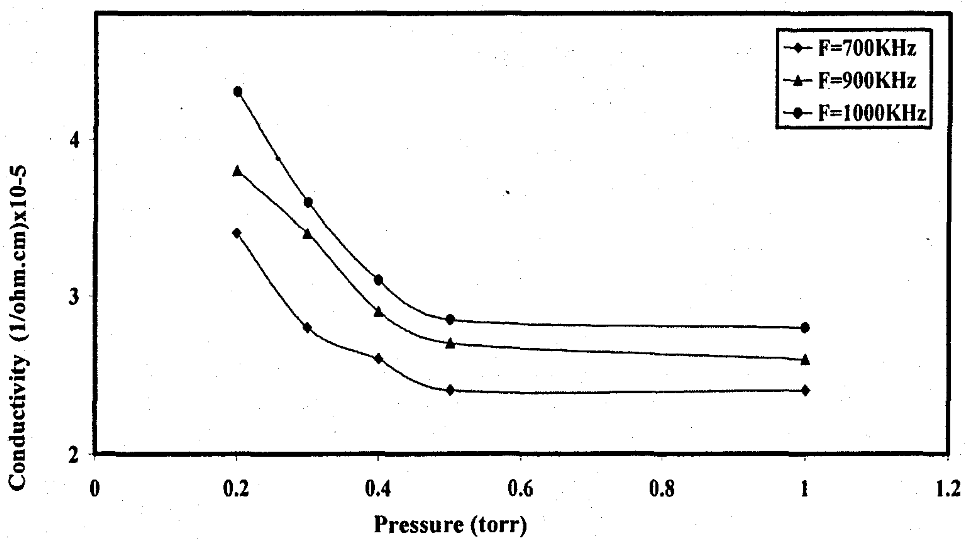
Fig(9):Radial Distribution of Radial Electric Field for Different A.C-Amplitude



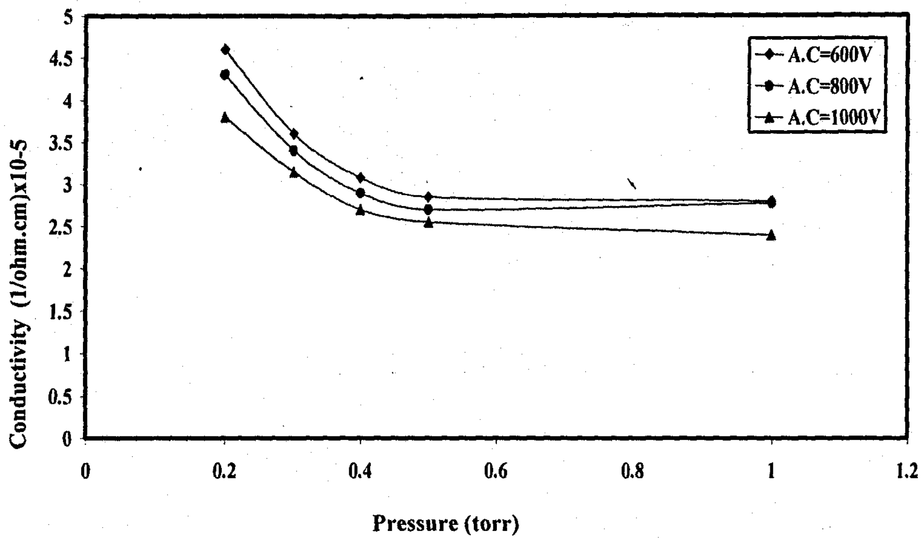
Fig(10):Electrical Conductivity as a Function of Frequency of R.F Source for Various Discharge Currents



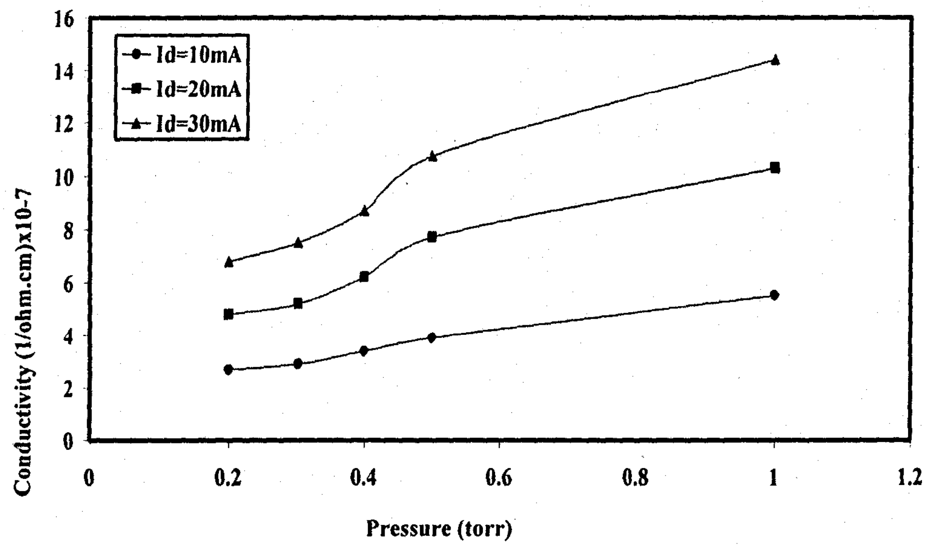
Fig(11):Electrical Conductivity as a Function of A.C Amplitude of R.F Source for Various Discharge Currents



Fig(12):Electrical Conductivity as a of Pressure for Different Frequency



Fig(13):Electrical Conductivity as a Function of Pressure for Different A.C-Amplitude



Fig(14):Electrical Conductivity Variation with the Pressure for Various Discharge Currents