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Study of Current - Voltage Characteristics of Normal and Abnormal Glow Discharge in Air at Low Pressures

Ahmed Y. Owaid
Department of Electronics, Technical Institute of Mosul, Northern Technical University, Mosul, Iraq
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Corresponding Author:
Name: Ahmed Y. Owaid
E-mail: ahmedowaidphysics@nut.edu.iq
Tel:

ABSTRACT

In the present study experimental measurements have been carried out to investigate the variation of air discharge voltage (V) and current (I) as a function of working pressure (p), in the ranges (300-500 V), (2-15 mA) and (0.09-0.13 Torr) respectively. Two thick, flat and circular electrodes of radius (4 cm) of Aluminum with a Pyrex cylinder tube of length (10 cm) and radius (3.5 cm) were used to generate the air glow discharge modes. The (V-p) characteristics have shown that an increasing in the discharge voltage of normal mode and reduction in that of abnormal mode with increasing the working pressure. It also displayed that the range of upper voltage from breakdown to abnormal glow has a minimum value (15.7 V) at (0.117 Torr). In addition to that, it is found that the (I-V) characteristics of air glow discharge modes are consistent with those reported in the literature for other gases, as argon, hydrogen and oxygen. It is expected that these observations can help to reduce the voltage needed to get an intense abnormal glow discharge in the air, and to understand well the behavior of two modes of glow discharge, that is important in various applications.

Introduction

Glow discharges are widely used in the industrial applications of plasma. Hence, it is very important to support the database of glow discharges continually by a new data, from both experimental and theoretical studies. One of the most important index in glow discharges is the gas pressure [1-4], therefore the study of pressure effects on the glow discharge current-voltage characteristics has significant interest. It is well-known that glow discharge is characterized by different discharge modes [1-6], these are the subnormal glow, the normal glow and the abnormal glow. The discharge with positive space charge between Townsend discharge and normal glow discharge is known as subnormal glow discharge and has a negative slope of (I-V) characteristic [1,3]. In normal glow mode, the current increases with an applied voltage by a nearly constant current density (the voltage across the electrodes also remains relatively constant) [1]. It means that the plasma is in contact with only a part of the cathode surface, that can be increased with increasing the current. In the abnormal mode the current increases are forced by increasing the discharge voltage and the plasma completely covers the cathode surface and the whole volume of the chamber is occupied by an intense glow discharge [1-4].

Several studies investigated the (I-V) characteristics of air glow discharge plasma. The study in [7] shows an exponential dependence of discharge current with discharge voltage of subnormal glow discharge of air at low pressures. The reference [8] reported that the (I-V) characteristics of air DC glow discharge at low pressure, show a considerable change in the discharge current with discharge voltage. Authors in[9] reported the influence of discharge voltage and pressure on the parameters of air glow discharge. In the present study, the influence of a low gas pressure on the discharge voltage and current of glow discharge modes of air are investigated experimentally .

Experimental setup

The experimental arrangement is shown in Figure (1). The discharge chamber used is a cylindrical tube of length (10 cm) and inner diameter (7 cm) made of a thick glass. The plasma is produced inside the tube by using two flat, thick and circular electrodes of radius (4 cm) made of Aluminum, fitted on the two ends of the discharge tube. By a vacuum system (VS) the pressure (0.09-0.13 Torr) inside the tube is produced

by a rotary pump, controlled by a needle valve and measured by a Pirani gauge.

It is well-known that the low frequency AC voltage acts as a DC one in gas discharges [1,3]. Because of the low cost of AC power supply in comparison to a DC source, A high voltage of 50 Hz in the range (400-700V) was applied to the electrodes from a high discharge voltage unit (HDV) to produce the two modes of glow discharge of air. A high input impedance oscilloscope (OSC) is connected across the discharge electrodes to measure the discharge voltage. A carbon resistance, (R, 470 ohm 2 pwatt) is connected in series to the discharge circuit to measure the discharge current on the second channel of the oscilloscope.

It is important to know that the distance between the electrodes (d) fixed at (10 cm) and only the pressure (p) was changed within that range to get the (V-p) and (I-V) characteristics of air glow discharge at different (pd) values (pressure times inter-electrodes distance), on the right side of Paschen curve minimum (0.6 Torr.cm) [1]. All voltage and current values that will be stated in the results and figures are represent the root mean square values.

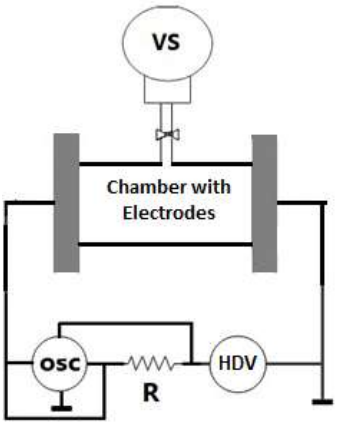

Figure 1. Experimental set-up

Results and Discussion

The variations of air discharge voltage with working pressure are shown in figure (2). The (V-p) characteristic displays two distinct regions of operation of glow discharge: a low voltage region (normal glow discharge) and a high voltage region (abnormal glow discharge). The normal glow discharge is achieved by a voltage slightly greater than the breakdown voltage with current ($I < 4$ mA), while the abnormal glow discharge is ignited by a high voltage that it is sufficient to produce an intense glow discharge of current (4 mA $< I < 12$ mA).

In the low voltage region, figure (2) shows that, the discharge voltage increases with increasing of the working pressure. This result matches with the right – hand side of Paschen curve [1-4]. It is also observed that the discharge voltage decreases slightly with increasing discharge current, at all pressures under consideration. This result is consistent with the normal glow discharge mode properties [1-3,7].

Figure (2) also indicates that the difference between breakdown voltage and normal glow discharge voltage increases with increasing of the pressures. This is due to an increase in the electron collision frequency and a decrease in the electron energy with increasing the working pressure [9].

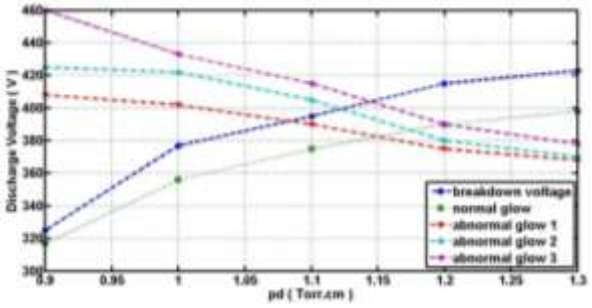

Figure 2. (V-p) characteristics of air glow discharge

In the high voltage region, figure (2) shows a decrease in discharge voltage with increasing of the working pressure, for three modes of operation of abnormal glow discharge (abnormal glow1, abnormal glow 2 and abnormal glow 3). It is also observed that the voltages that needed to produce three convergent modes of intense or abnormal glow discharge tend to decrease with increasing pressure. This is due to the increasing in the electrons mobility , drift velocity and density by increasing of the working pressure [1,3,10].

An important result is obtained from figure (2) and plotted in figure (3) with a fitting curve of Matlab program, that the range of upper voltage from breakdown to a third mode of abnormal glow has a minimum value (15.7 V) at (1.17 Torr.cm). This is due to the intersection of the common properties of the two regions of operation of the discharge at this pressure. This result can be employed to reduce the power dissipation in the two regions of glow discharge.

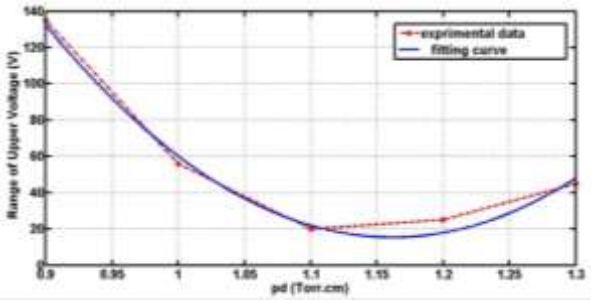

Figure 3. The range of upper voltage of glow discharge of air as a function of working pressure with fitting curve

The (I-V) characteristics of two modes of glow discharge are shown in Figure (4), and they are in agreement with those reported in the literature for other gases, as Argon, Hydrogen and Oxygen [1-3,11]. One can see that, the results that obtained from figure (2) are reflected in figure (4). From the latter figure it is clear that, in the low discharge voltage, the voltage decreases as soon as the discharge current

increased, for all working pressures in the range, and in the high voltage region the current increases on increasing the discharge voltage. Another observation can be obtained from figure (4), that at low pressures (0.09 – 0.1 Torr), the discharge current increases semi- horizontal with increasing the discharge voltage and as the pressure increases further the discharge current increases semi-vertical with increasing the discharge voltage. This is due to the space charge effects, which has no significant influence on the electric field profile at low discharge voltage and working pressure [1,8,11].

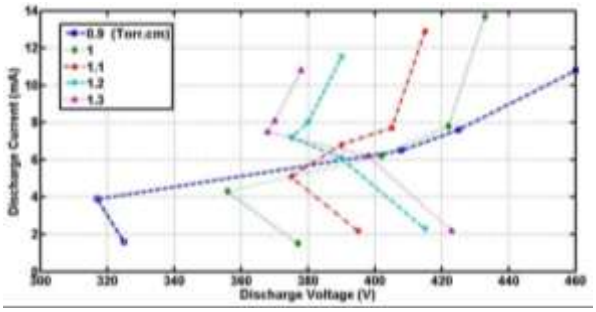

Figure 4. (I-V) characteristics of air glow discharge

Further result is obtained from (I-V) characteristics and plotted in figure (5) with a fitted curve of Matlab program, that the difference between breakdown current and the third abnormal glow current has a semi Gauss curve when it changes with discharge pressure, and a maximum value (12.2mA) is obtained at (0.98 Torr.cm). This can be explained that, the glow discharge of air has a minimum impedance at this pressure.

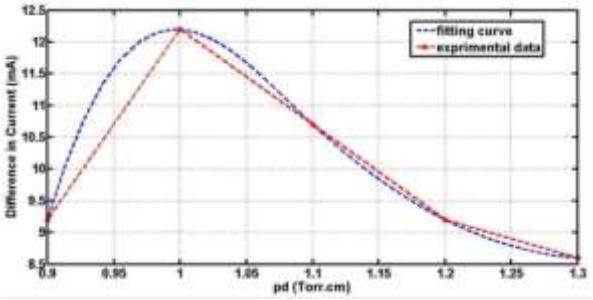

Figure 5. The difference between breakdown current and a third abnormal glow current as a function of working pressure with fitting curve

Conclusion

The following observations are made with respect to the present experimental data. First, there are two modes of operation of glow discharge of air in that range of voltage and pressure, normal and abnormal modes. Second, increasing the pressure results in increasing and decreasing the discharge voltage of normal and abnormal modes, respectively. Third, the range of voltage of normal mode increases with increasing the working pressure, while that of abnormal mode decreases. Fourth, the range of upper voltage from breakdown to a third mode of abnormal glow, first drops sharply by increasing the working pressure then returns to increase with pressure in the range, and has a minimum value (15.7 V) at (1.17 Torr.cm). This observation may be used to save the power needed to produce two modes of glow discharge. Fifth, there are two trends to change the discharge current with discharge voltage, semi-horizontal at pressures (0.09-0.1 Torr) and semi-vertical at pressures (0.1 - 0.13 Torr). In general, the (I-V) characteristics of two modes of glow discharge are in agree with that was reported in references [1,11] for argon, hydrogen and oxygen. Further work is necessary to quantify more accurately the smallest range of upper voltage that is needed to produce an intense glow discharge (abnormal mode) with a minimum power dissipation.

References

[1] Raizer, Y. P. (1991). Gas discharge physics. *springer, Berlin, Germany*: 8-25 pp.,35-37 pp.,167-185 pp.

[2] Chapman, B. (1980). Glow discharge processes. *Willey, New York*: 77-106 pp.

[3] Howatson, A. M. (1976). An Introduction to gas discharges. 2nd edn., *Pergamon Press Ltd*: 85-102 pp.

[4] Braithwaite, N. St. J. (2000). Introduction to gas discharges. *Plasma sources Science Technology*, **9** : 517-527.

[5] Bogdanov, E. A.; Demidov, V. I.; Kudryavtsev, A. A. and Saifutdinov, A. I. (2015). Is the negative glow plasma of a direct current glow discharge negatively charged. *Physics of plasmas*, **22 (024501)**: 1-4.

[6] Kulkarni, S. V.; Panchali, D.; Kumari, V. and Bora, D. (1996). Characteristics of abnormal glow discharge. *IEEE International Symposium on electrical insulation*, **2**:789-792.

[7] Pradhan, S. S. (2016). Characteristics of subnormal glow discharge in longitudinal magnetic field in air. *journal of physical sciences*, **21**: 139-144.

[8] Lisovskiy, V. A. and Yakking, S. D. (2000). Experimental study of a low pressure glow discharge in air in large diameter discharge tube station. *Plasma Physics Resort*, **26 (12)**:1066-1075.

[9] Shrestha, A. K. *etal*. (2014). Influence of discharge voltage and pressure on the plasma parameters in a low pressure dc glow discharge. *International journal of recent research and review*, **7 (2):**9-15.

[10] Wissel, S.; Zwicher, A.; Ross, J. and Gershman, S. (2013). The use of DC glow discharges as undergraduate educational tools. *American Journal of Physics*, **81** (**9**):663-669.

[11] Lisovskiy, V. A.; Artushenko, K. P. and Yegorenkov, V. D. (2016). Normal mode of DC

discharge in Argon, Hydrogen and Oxygen. *Problem of atomic science and technology*, **22 (6)**: 223-22.

دراسة خواص التيار – الفولتية للتفريغ المتوهج العادي وغير العادي للهواء عند ضغط واطئ

احمد يونس اعويد

قسم التقنيات الالكترونية ، المعهد التقني الموصل ، الجامعة التقنية الشمالية ، الموصل ، العراق

الملخص

في هذه الدراسة اجريت قياسات عملية لاستقصاء تيار وفولتية تفريغ الهواء كدالة لضغط الاشتغال في المديات (300–500) فولت ، (2–15) ملي امبير و (0.09–0.13) تور. لقد استخدمت اسطوانة زجاجية صلدة بطول (10) سم ونصف قطر (3.5) سم مع قطبين بشكل قرصين سمكين، مسطحين ودائريين بنصف قطر (4) سم من الالمنيوم لغرض توليد نمطي التفريغ المتوهج للهواء. اظهرت قياسات خواص (الفولتية – الضغط) بان زيادة الضغط تؤدي الى زيادة فولتية التفريغ المتوهج العادي ونقصان فولتية التفريغ المتوهج غير العادي، ومن هذه الخواص لوحظ ايضا بان مدى الفولتية العليا لنمطي التفريغ من فولتية الانهيار الكهربائي الى فولتية التفريغ المتوهج غير العادي يمتلك قيمة صغرى تقدر تقريبا (15.7) فولت عند الضغط (0.117) تور. بالإضافة الى ذلك لوحظ بان خواص (التيار – الفولتية) المقاسة لنمطي تفريغ الهواء المتوهج تتوافق مع تلك الخاصة بغازات اخرى مثل الاركون والهيدروجين والاوكسجين والمتوفرة في دراسات سابقة. نتوقع بان نتائج هذه الدراسة يمكن ان تساهم في تقليل الفولتية اللازمة لتوليد التفريغ المتوهج غير العادي في الهواء فضلا عن زيادة فهم طبيعة هذين النمطين من التفريغ والذين يمتلكان اهمية في العديد من التطبيقات العملية.