Republic of Iraq
Ministry of Higher Education
& Scientific Research
University of Kufa
College of Science / Phy. Dep.
Al-Kufa Journal of Physics

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة الكوفة
كلية العلوم
قسم الفيزياء
مجلة الكوفة للفيزياء

ISSN ٢٠٧٧ - ٥٨٣٠
مجلة علمية محكمة تصدر عن قسم الفيزياء كلية العلوم جامعة الكوفة

العدد : ١٤٩٥
التاريخ : ٢٣/٥/٢٠١٨

Ref :
Date :

JONRNAL OF KUFA - PHYSICS

م/ قبول نشر

الى الباحث السيد : عبد الحسين عباس خضير
وسام محمود طاهر

تدارست هيئة التحرير البحث المقدم من قبلكم والموسوم:

**دراسة تأثير الشكل الهندسي للكاثود على خصائص (I-V) لتفريغ توهج النتروجين في التيار المستمر .**

وبعد الإطلاع على أراء المقيمين ، قررت هيئة التحرير في جلستها المرقمة (المنة) والمنعقدة في 2018/5/23 قبول البحث وسينشر في المجلد (العاشر) العدد (الثاني) مع التقدير.

أ.د .عادل حبيب عمران
مدير التحرير

نسخه منه الى :
المجله العلميه للارشيف

العنوان : العراق - النجف الاشرف - جامعة الكوفة - كلية العلوم - قسم الفيزياء
P.O.BOX(221)Najaf.IRAQ

# Study the effect of cathode geometry on I-V characteristics of nitrogen dc glow discharge

**Dr. Abdul hussain A. Khadayeir[1] , Wessam M.Taher[1]**

[1](physics Department, College of Education/ University Al-Qadisiyah, Iraq country)

E-mail:abdulhussain.Khadyair@qu.edu.iq

**ABSTRACT**: In this paper, the I-V characteristic of a dc glow discharge are studied with the aim of determine the performance a good parameters for stable operation of the plasma. Nitrogen plasma produced by dc glow discharge is the investigated with a many purpose of studying plasma phenomena, the discharge system consists of two electrodes, the cathode forms various geometrical shapes and anode as a disc- shaped with diameter (8.8cm). The electrodes are enclosed in a large cylindrical glass chamber of pyrex filled with nitrogen gas. Two important physical parameters affecting the condition of the discharge are the gas pressure and constant inter-electrode distance. The discharge current-voltage (I-V) characteristic curves of the discharge were measured at variable pressure and the inter-electrode spacing, Current-voltage characteristics visualization of the discharge indicate that the discharge is take place in the normal glow region. The( I-V) characteristics of nitrogen gas discharge were deduced as a plasma system operated in normal glow discharge nitrogen, which is very important parameter in the sputtering and deposition. Also the discharge current is increased for nitrogen plasma discharge with the increasing of the working pressure lead to increase the deposition rate.

**Keyword**: Dc glow discharge, Hollow cathode, Plasma parameter, Gas pressure, Current discharge

دراسة تأثير الشكل الهندسي للكاثود على خصائص(I-V) لتفريغ توهج النتروجين في التيار المستمر

**الخلاصة**: في هذا البحث، تمت دراسة الخواص الكهربائية لألواح تفريغ التيار المتوهج DC بهدف تحديد افضل المعلمات الجيدة للتشغيل المستقر للبلازما. يتم فحص البلازما النيتروجينية الناتجة عن تفريغ الوهج (DC) لأغراض كثير لدراسة ظاهرة البلازما ، يتكون نظام التفريغ من قطبين ، يشكل الكاثود أشكال هندسية مختلفة والأنود يكون على شكل قرص قطره (8.8cm) . يتم وضع الأقطاب الكهربائية في غرفة زجاجية أسطوانية كبيرة من الباركس مليئة بغاز النيتروجين. اثنين من المعلمات المهمة التي تؤثر على حالة التفريغ هي ضغط الغاز والمسافة بين الاقطاب. تم قياس منحنيات تيار التفريغ للجهد الكهربائي (I-V) للتفريغ عند ضغط تشغيل متغير وتباعد ثابت بين الأقطاب الكهربائية، يشير تصور خصائص التفريغ (تيار- فولت) إلى أن التفريغ يعمل في منطقة التوهج الطبيعية. تم استنتاج خصائص I-V لتفريغ غاز النيتروجين كنظام بلازما يعمل في تفريغ الوهج الطبيعي، والذي هو معلمة مهمة جدا في الترذيذ، الترسيب. كما ان زيادة تيار التفريغ لتفريغ بلازما النتروجين مع زيادة ضغط التشغيل يؤدي الى زيادة معدل الترسيب.

**الكلمات المفتاحية** :التفريغ المتوهج، الكاثود المجوف، معلمات البلازما، ضغط الغاز، تيار التفريغ

## 1. INTRODUCTION

The research into the conditions of the dc glow discharge is of large interest, where DC glow discharges are applied more general for depositing thin films, plasma polymerization, etching, oxidation, and pumping gas discharge lasers, etc. [1]

The low pressure glow discharge plasma is generating by applying a potential difference between two electrodes. Since there is a continuous in the loss of electrons in the discharge, there must be an equal degree of simultaneous ionization to maintain a stable discharge. Other

electrons are produced by secondary emission from the cathode surface [2]

The basic characteristics of plasma discharge like the breakdown voltage and the voltage – current characteristics depends on the geometry of the electrodes, pressure in the chamber , the container, electrodes material, type of gas used and the external circuit.[3]

The radiation is the result of ion or electron interaction with others particles in the plasma. Because of their velocity, electron interaction tend to controlled the elastic and inelastic collision excitation and ionization processes [4]

Radiation intensity is dependent on the current intensity on the cathode surface as well on the value of the electron current supplying the anode [5]

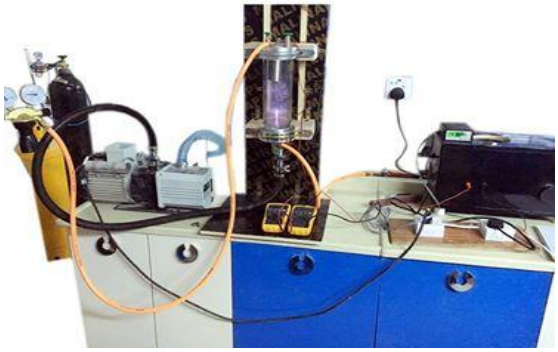
Cold cathode gas discharges need low-pressure for a glow to be permanent. In recent years, low pressure DC glow discharges were draw attention in polymer surface modification primarily for stripping photoresists [6]

Actually, different studies took advantage of various DC glow discharge strategies and configurations for plasma treatment of polymer surfaces for different applications Hino et al [7] made use of a dc glow discharge that make use of a biased cylindrical hollow copper anode for the treatment of silicone rubber deposited on an alumina substrate using a mixture of $H_2$, Ar and $O_2$ gases. The study was done to demonstrate the applicability of micro fabrication techniques used for silicon etching in make biomaterials. Pandirayaj et al [8] made use of a typical low-pressure glow discharge tube with air plasma to increase the Polyethylene terephthalate (PET) films' adhesion to metallic coatings. Air plasma was induced on the polymer surfaces that were facing perpendicular to the discharge axis between two aluminum parallel electrodes.

The present work aims to study the effects of both pressure and cathode geometry (diameter and depth of hollow cathode) , on the glow shape, characteristics I-V , as well as on the luminous intensity emitted from the positive column of nitrogen glow discharge plasma (NGDP)

## 2. Experimental Equipment

The DC glow discharge system is made home consists of two parallel electrodes One of them is movable (represent cathode) and the other fixed electrode on disc form (represent Anode) ,with Diameter (8.8)cm, .The cathode is used in three geometric forms(cylindrical with height (8cm) and inner diameter(6cm) ,conical with height (8cm) , inner diameter (6cm) and the bottom diameter(2cm) ,and disc with diameter(6cm) enclosed in a cylinder chamber of glass Pyrex with length 30 cm and 10cm diameter. A schematic diagram of the device used in this investigation shown in Figure (1). The discharge was operated in DC mode at pressures from 0.085 to 0.7 mbar for nitrogen gas, the external resistance(R). and digital multi-meters were connected to measure the discharge current and the voltage. Basically, he discharge chamber was evacuated using rotary pump (TRIVAC-D16E of 16 m3/h), and the gas pressure was monitored by perani type (Edward's). The applied voltage was controlled by a DC power supply which can produce voltage up to 2 KV.



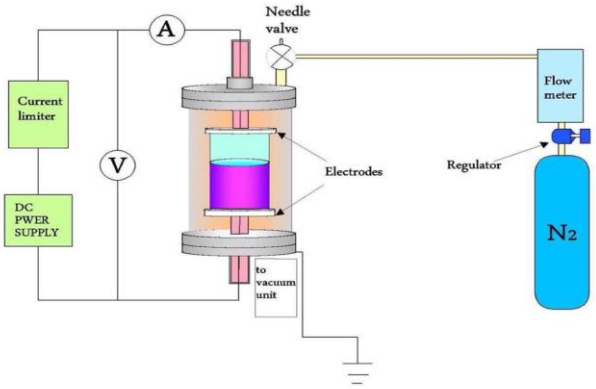



Figure1 (a) represents discharge unloading system dc (b) illustrates the scheme for electric circuit

## 3. Results and discussion

The electrical characteristics of discharge plasma, like dependency of discharge current on the applied voltage and gas pressure inside the vacuum, are of importance to introduce the homogeneity of the generated plasma. In the following, these characteristics are presented in the following forms 2(a, b, c) the discharge current is measured as a function of discharge voltage at different operating pressure (0.085, 0.1, 0.25, 0.4 and 0.7 mbar) for constant inter-electrode distance (d=4cm). The current changes by changing the dc power supply voltage. Electric field accelerates the electrons and particles which collide with gas molecules leading to increase the discharge current and gas temperature. In this mode lead rise of the current due to rise of the current density on the cathode surface, hence, to an increment of the voltage.

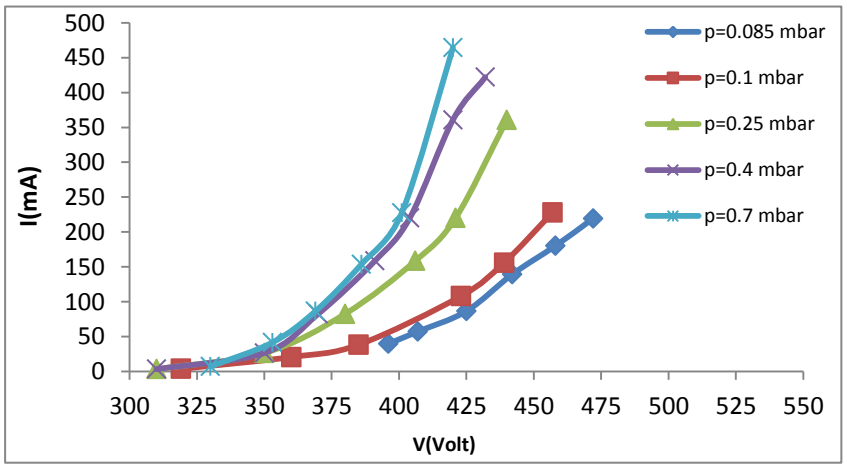
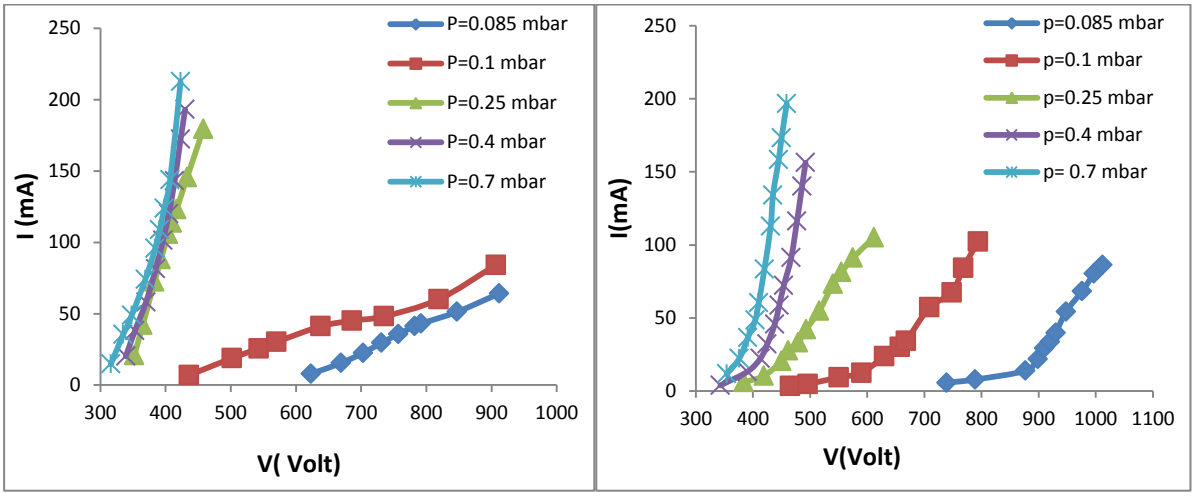



Figure 2 (a) I-V Curve of glow discharge of cylindrical hollow cathode




(b) I-V Curve of glow discharge of conical hollow cathode, (c) I-V Curve of glow discharge for cathode disc

The results show that the relationship between current and voltage of a glow discharge is non-linear. As that current rises due to an increasing in the cathode fall. Therefore, the voltage over the electrodes rises pointedly. From fig (2.a), it has been found that the increase in the discharge voltage is accompanied by an increase of the discharge current, where discharge characteristic are characterized by normal glow. Here, the discharge current is proportional to applied drop voltage seems to fit quite well with experimental data of previous studies [9]. The discharge current was increased for nitrogen plasma discharge with the increasing operating pressure; this can be explained as following statement: The mean free path of a molecule in gas is the average distance between the collisions of molecules. This is inversely proportional to gas pressure. Where the accelerated electron will acquire enough energy to ionize an nitrogen atoms. This electron will in turn be accelerated, lead to another collision. A chain reaction then causes breakdown voltage and a glow discharge takes place from the cascade of released electrons. At low working pressure, the electrons mean free path can become long compared to the gap between the electrodes. [10]. Examinations at various pressures emphasizes, that although the ion currents are usually interpreted in terms of gas pressure, it is more accurate to consider the gas density. If the gas pressure is increased the gas density increased leads to increase the ion current. This is indicated that the ions may undergo several collisions during their paths through the dark space region .It is important to realize that several processes operate simultaneously within the plasma ,also excitation, fragmentation and ionization may occur [11] .

Figure (2.b) and (2.c) shows both the behavior of the electrical discharge at pressures and voltages are variable. Figure 3.a show the regions of the I-V curve are observable of pressures than ($8.5X10^{-2}$ - $7X10^{-1}$) mbar. At pressures breakdown rapidly followed by a transition to the normal glow discharge mode where the discharge voltage is relatively constant. When the pressure is increased, the average discharge voltage is found to decrease from approximately 650 volt at ($8.5X10^{-2}$) mbar to 425 volt at ($1x10^{-1}$) mbar at inter-electrode spacing of 4 cm. Evidently as the pressure is raised the discharge becomes more conductive. The dependence to nonlinear at short gap distance (electrodes spacing)or when decrease pressure, but becomes linear at larger gaps or increase pressure. This is representative of an increase in the length of the positive column in the discharge where the electric field remained constant or increase in the electric field by increasing the pressure at electrodes spacing constant,[12] The slope and vertical displacement of the current increases at higher pressure, reaching its saturation at pressure ranging at( 0.25 – 0.7) mbar. Maximum increase in the current was observed at 0.7 mbar.

At figure (2.c)showed that the (I-V) characteristic were different When using the cathode in a disk format, the average discharge voltage is found to decrease from approximately 725 volt of ($8.5X10^{-2}$) mbar to 450 volt at ($1x10^{-1}$) mbar at inter- electrode spacing of 4 cm. Evidently as the pressure is

raised the discharge becomes more conductive. It was observed that the increase in current was nonlinear by increasing the pressure of nitrogen gas, The discharge current was increased for nitrogen plasma discharge with the increasing operating pressure, The increase in pressure leads to an increase in current and the reason for this: To increase the ionization cross-section of $N_2$ [13].

## 4. CONCLUSIONS

In this work, we can conclude the following. First, the I-V characteristics of gas discharges indicate that the plasma system operated in abnormal glow discharge region, which is important parameter in microelectronic manufacture. Second, gas pressure, the cathode geometry and cathode potential it has a great effect on the glow discharge current, and satisfied a good agreement with Child –Langmiur equation. Finley, the present investigations show that an increase of the discharge voltage was lead to an increase of the discharge current; this dc-glow discharge system can be used for sputtering.

## REFERENCES


[1] Hassouba, M. A., and E. A. Mehanna. "Electrical characteristics of (N2-H2) gas mixture DC glow discharge." International Journal of Physical Sciences 4.11 (2009): 713-721.

[2] Grill A, "Cold Plasma in Material Fabrication from Fundamental to Applications", IEEE Press, 1993.

[3] David Staack, Bakhtier Farouk, AlexsanderGutsol and Alexsander Fridman, "Characterization of a dc Atmospheric Pressure Normal Glow Discharge", Plasma Science and Technology .14(2005) 700-711.

[4] Abdou A. Garamoon, Ahmed Samir, Farouk Fahmy Elecshar, A. Nasai, and Eizaldeen, FKotp, " Spectroscopic Study Of Argon DC Glow Discharge", IEEE Transaction on Plasma Science ,Vol. 35, No. 1, February ( 2007).

[5] Mazurek, B., A. Nowak, and A. Tyman. "X-ray emission accompanying cathode micro discharge." IEEE transactions on electrical insulation 28.4 (1993): 488-493.

[6]Garbassi, F., M. Morra, and E. Occhiello. "Polymer Surfaces, revised and updated ed." (1998).

[7]. Hino, T. et al, “Surface wettability of silicon rubber after irradiation with a glow discharge plasma”, Vacuum 83 (2009): 506-509.

[8]. Pandiyaraj, K.N., V. Selvarajan and R.R. Deshmuch, “Effect of operating parameters on DC Glow discharge plasma induced PET film surface”, 23rd National Symposium on Plasma Science & Technology, Journal of Physics: Conference Series 208(2010): 1-7

[9] Lisovskiy, V. A., S. D. Yakovin, and V. D. Yegorenkov. "Low-pressure gas breakdown in uniform dc electric field." Journal of Physics D: Applied Physics 33.21 (2000): 2722

[10] Garamoon, A. A., et al. "Electrical characteristics of a DC glow discharge." Plasma Sources Science and Technology 12.3 (2003): 417

[11] Chapman, Brinan. "Glow Discharge Processes: Sputtering and Plasma Etching, John Wiley & Sons." New York (1980)..

[12] Chiad, B. T., et al. "Construction and characterization of a low pressure plasma reactor using DC glow discharge." Journal of Optoelectronics and Biomedical Materials 1.3 (2009): 255-262.

[13] Naveed, M. A., et al. "Langmuir probe and spectroscopic studies of RF generated helium-nitrogen mixture plasma." The European Physical Journal D 47.3 (2008): 395-402