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Influence of Inter-Electrode Distance, longitudinal Magnetic Field on Breakdown Voltage in Plane-Parallel Plasma Discharge

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ABSTRACT

Designed a home – made dc magnetron plasma discharge system Townsend electrical by cathode potential of 100-700 V and discharge gas pressure of (0.055-1.5) mbar has been investigated. In this paper studies voltage the breakdown of argon at different inter-electrode distance and longitudinal magnetic field in DC electrical discharge. The longitudinal magnetic field generated by pair of permanent magnets, which produces a high flux density ($B = 640$ Gauss) at the electrode surface and inter-electrode distance was (2, 4, 6, 8) cm. The results showed a decreases breakdown voltage when inter-electrode distance decreases and the breakdown voltage decreases by applying the magnetic field.

Introduction

The characteristics of electrical breakdown of several gases under the effect of applied magnetic field have been subjected for the purpose of exploring the better understanding of the complex mechanisms of gas discharge in many researches. These researches contained the study of magnetized plasma discharge at different working parameters such as the gas pressure, the geometry of electrodes and the materials, pumping gases, type of applied voltage, humidity of discharge chamber and the chamber temperature [1] [4].

In previous studies [3,4]. An experimental device has been developed to observe the effect on the gas breakdown of a magnetic field parallel to the electric field. The lateral diffusion of electrons expected to be hindered by the magnetic field consequently reducing losses and enhancing the ionization efficiency in the Townsend regime. In fact, as the experimental results show, this phenomenon was confirmed by the reduction of the breakdown voltage when a magnetic field was applied.

Breakdown potentials under the presence of a longitudinal magnetic field can be measured in the Townsend discharge regime. The electrons in the tail of the energy distribution function have enough energy to ionize the gas atoms in this regime. The secondary electrons thus presented can also create a

sufficient amount of energy from the electric field to ionize atoms and produce new electrons. This leads rise to an avalanche-like growth of the degree of ionization. In order to obtain this, the loss of electrons should be rather small. The electron losses can be seen by recombination with ions as a result of diffusion toward the walls and also to the case of electronegative gases, as a consequence of the formation of negative ions.

Gas discharge breakdown voltage V_B is the minimum voltage required for initial breakdown of discharge. Paschen has found through experiment the function between gas discharge breakdown voltage and the product of gas pressure (p) and cathode-anode distance (d), Before Townsend proposed the gas discharge breakdown theory. The Paschen law expression of Townsend discharge [6]. Can be shown clearly in the following [5] :

$$V_B = \frac{B(pd)}{\ln[A(pd)/\ln(1+\frac{1}{\gamma})]} = f(pd) \quad (1)$$

P is the pressure so A and B are constants for a particular gas, secondary electron emission coefficient γ depends on the cathode material and gas type Fig (1) is shown Paschen curve.

Aims of the study the purpose of this work is studies voltage the breakdown of argon at different inter-electrode distance and longitudinal magnetic field in

DC electrical discharge by using a pair of permanent magnets on the electrical breakdown in gas (Ar) .

Theoretical Part

A Paschen curve can also be created according to equation (1) in order to present the active association between gas discharge breakdown voltage and the product pd of discharge gas pressure p and cathode-anode.

The existence of a minimum breakdown voltage in Paschen's curve may be explained as follows :

For values of $pd > (pd)_{min}$, electrons crossing the gap make more frequent collisions with gas molecules than at $(pd)_{min}$, but the energy gained from the collisions is lower.

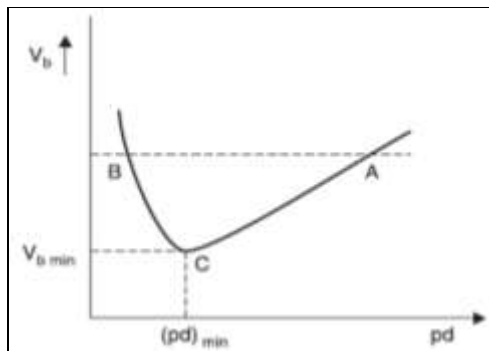


Fig. (1).Paschen's law curve [7].

The existence of a minimum breakdown voltage in Paschen's curve may be explained as follows:

For values of $pd > (pd)_{min}$, electrons crossing the gap make more frequent collisions with gas molecules than at $(pd)_{min}$, but the energy gained between collisions is lower. Hence, to maintain the desired ionization more voltage has to be applied. For $Pd < (Pd)_{min}$, electron may cross the gap without even making a collision or making only less number of collisions. Hence, more voltage has to be applied for breakdown to occur [7,2]. The interest in studying the magnetic field effect on the characteristics of electrical breakdown and on the properties of a Townsend discharge is motivated by a necessity of gaining a better understanding of the complex mechanisms of gas discharge phenomena and also because the B-field may contribute favorably for dealing with practical problems associated with the use of this kind of discharge for plasma processing technologies [8, 7].

Experimental setup

The experimental set-up used in this work. A cylindrical pyrex glass vacuum chamber with length and diameter of 35 cm and 14.5 cm respectively has been used for plasma discharge. Basically, the inside of the chamber consists of two electrodes with 7.25 cm diameter and thickness (3mm) between which the breakdown - discharge is formed the electrodes are made of stainless steel material and each of them. Two annular concentric magnets were placed behind each electrode to form the magnetically configuration, and gas supply feed through were inserted into the chamber, also the chamber included

one side four feed through for vacuum. The discharge chamber was evacuated by a two-stage Edward rotary pump and the vacuum inside chamber was measured by Pirani gauge connected to a vacuum controller from Edward controllers (1105). A gas was supplied to the chamber through a fine-controlled needle valve (0-160 sccm) to control the gas pressure inside the chamber. The longitudinal magnetic field generated by pair of permanent magnets, which produces a high flux density ($B = 0 - 855$ Gauss) at the electrode surface, the combination of the two magnets allows for lower pressure operation than either magnet alone. Two permanent circular magnets are placed behind the electrodes surface to produce the magnetic field.

Fig. 2 can be shown clearly the schematic diagram of the system the experimental set-up used in this work.



Fig.(2) a photograph of the main experimental set-up used in this work.(1) plasma chamber ((a) cathode (b) anode)) (2) ammeter and voltmeter (3) needle valve(1-160 sccm) (4) vacuum system (5) current limited discharge resistance (6) flow meter and gas mixer (7) H.V power supply

Results and discussion

Breakdown Voltage and Paschen Curves: the profile of breakdown voltage versus Pd (where P is Pressure and d is anode-cathode distance) which is well-known as Paschen curve can be shown clearly Figure (3). The existence of a minimum breakdown voltage in Paschen's curve may be explained as follows: For values of $pd > (pd)_{min}$, electrons crossing the gap make more frequent collisions with gas molecules than at $(pd)_{min}$, but the energy gained between collisions is lower. Electron may cross the gap without even make a collision or make only less number of collisions to maintain the desired ionization more voltage has to be applied. For $pd < (pd)_{min}$, so, more voltage has to be applied for breakdown to occur [2, 4].

The breakdown curves for argon we measured with different inter-electrode distance. By giving a look to this figure, it can be concluded that on increasing the gap d the curves is shifted both to the region of higher breakdown voltages, and simultaneously to higher Pd values. This shift of the breakdown curves to higher V_b and Pd values with the increase of the inter-electrode distance d is associated with the growth of the losses of charged particles on the lateral walls of the discharge tube due to the diffusion across the electric field [9].

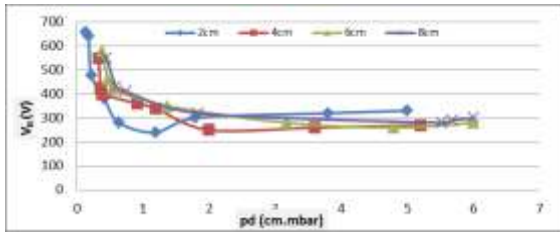


Fig. (3) Measured breakdown curves of the breakdown discharge in argon and different inter-electrode gaps without magnetic field

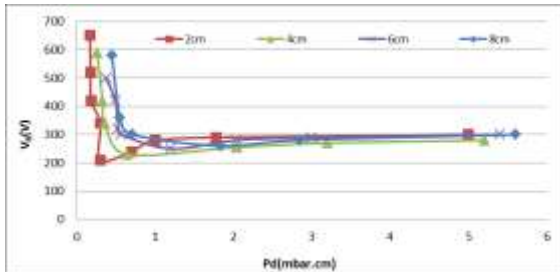


Fig. (4) Measured breakdown curves of the breakdown discharge in argon and different inter-electrode gaps within longitudinal magnetic field

Figure (3,4) shows the breakdown voltage of Ar as a function of (Pd), for various values of magnetic field (B). The (Pd) min of Paschen's curve shift to low pressures when magnetic field increases, and at higher pressures the effect of magnetic field decrease.

Table (1) the variation of breakdown voltage (Pd) min with Different inter-electrode gaps

Without magnetic field at flow = 30sccm	D=2cm	D=4cm	D=6cm	D=8cm
Breakdown voltage Vbmin(V)	240	250	260	280
pd min(mbar.cm)	1.2	2	4.8	5.5
With magnetic field				
(Breakdown voltage Vbmin(V)	210	230	250	260
(pd min(mbar.cm	0.4	0.48	1.2	1.8

Conclusion

The main results of this work can be concluded as follows: As the inter electrode distance increased the breakdown voltage increases of range (2 to 8) cm.

References

[1] Sriram, D.; Jaina, K.K.(1997). "Effect of magnetic field on breakdown voltage characteristics of a multiage pseudo spark", *Appl. Phys. Lett*, **70** (23): 3093-3095.
 [2] Petraconi, G. et al. (2004). "Longitudinal Magnetic Field Effect on the Electrical Breakdown in Low Pressure Gases", *Brazilian J. Phys.* **34** (4):1662-1666.
 [3] Tan, I. H. et al. "Magnetic field effects on secondary electron emission during ion implantation in a nitrogen plasma", *J. Appl. Phys.*, **100** (033303):1-5.
 [4] Ohki, M. and Saito, S. (1991) "Effect of magnetic field on low-pressure gaseous breakdown along the surface of a solid insulator", *IEE Proceedings-A*, **138** (6):300-312.
 [5] Garamoonl, A.; Samir, A. ; Elakshar F. and Kotp, E. (2003) *Plasma Sources Sci. Technol.* Vol. (12):417-420.

Basically the application of a magnetic field on a electrical discharge has the equivalent effect of an increase of the gas pressure [10], is clear that the breakdown voltage V_B increases as magnetic field (B) increase. Thereby an increase of the breakdown voltage with increase of magnetic field after (V_b) min. Because the probability of collision decreases by decreasing the pressure, the magnetic field acts more efficiently for lower pressures so, enhancing the effectiveness of the magnetic confinement. The consequences of the action of the magnetic field can be expressed in the way that the electron the electron free paths across the residual gas are length ened and also that the lateral diffusion of the electrons can be reduced. These combined effects imply that the losses of electrons are reduced and they can now make more collisions with the gas molecules than they could do in the absence of the magnetic field. Ions produced near the cathode are more efficient in producing electrons by secondary emission. Ionization cascades are more probable and longer and ions strike the cathode more frequently. The self-sustained discharge situation is then less demanding on voltage at higher magnetic field confinement [11]. The table (1) shown the variation of breakdown voltage (Pd) min with Different inter-electrode gaps .

The results show that the effect of longitudinal magnetic field on the Paschen curves is to reduce the breakdown voltage, especially on the region of Pashen's minimum.

[6] Berzak, L. F.; Dorfman, S. E. and Smith, S. P. (2006) "Paschen's law in Air and Noble Gases" pag 1.
 [7] Naida, M. Kamaraju, S. V. (2009) "High Voltage engineering " Tata McGraw-Hill, 4th Edition..
 [8] J Wang, C. et al. *Appl. Phys.* **113** (033301).
 [9] Khalaf, M. K.; Agool, I. R. and Abd Muslim S. H. (2016) "Influence of Inter-Electrode Distance, Gas Mixing, Magnetic Field and Cathode Material on Breakdown Voltage of Lab-Made DC Magnetron Sputtering Device" Vol. (10)No. 4.
 [10] Wais, S. I.; Mohammed, R. Y. and Yousif, S.O. (2014) "Influence of Axial Magnetic Field on the Electrical Breakdown and Secondary Electron Emission in Plane-Parallel Plasma Discharge" Vol:5-08-23..
 [11] Miura, T.; Asmaki. T. (1996) "A theory on planar magnetron discharges", *Thin Solid Films*, (190):281– 282.

تأثير المسافة بين الأقطاب و المجال المغناطيسي الطولي على فولتية الانهيار في منظومة بلازما مستوية الأقطاب

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الخلاصة

في منظومة التفريغ الكهربائي محلية الصنع تفريغ تاونسند يتحقق عند ضغط (0,055 - 1,5) ملي بار وجهد بين (100 - 700) فولت. في هذا العمل تم دراسة فولتية الانهيار لغاز الأركون لمختلف المسافات بين الاقطاب وبتأثير المجال المغناطيسي الطولي للتفريغ الكهربائي بالتيار المستمر. المجال المغناطيسي الطولي يتولد باستخدام زوج من المغناطيس الدائمي، ينتج كثافة فيض عالي (B=855) كاوس والمسافة بين الأقطاب كانت (2, 4, 6, 8) سنتمتر. أظهرت لنا النتائج نقصان فولتية الانهيار عندما نقل المسافة بين الأقطاب، وكذلك تتناقص بتسليط المجال المغناطيسي الطولي.