Study the effect of longitudinal magnetic field and inter-electrode spacing on argon plasma discharges characteristics with Ti6Al4V alloy electrode.

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Abstract*:*

In this paper, the effects of magnetic field strength and the distance between the poles for argon dc electrical discharges on the Paschen's curves are studied for magnetic field strengths (0, 400, 855) Gauss and distances (2, 4, 6, 8)cm. It is found that the breakdown voltage is reduced by existence the magnetic field. Also the results showed that an increase on breakdown voltage as the distance between the cathode (Ti6Al4V) and the anode (stainless steel 316L) electrodes increase. On the other hand ,we found that less distance is less collapse in the effort. It is concluded that the DC electrical breakdown of the argon gas is facilitated if a longitudinal magnetic field is applied along the discharge axis.

Keyword: Breakdown Voltage; Paschen'sLaw; Magnetron Sputtering, Magnetic Field.

دراسة تأثير المجال المغناطيسي الطولي والمسافة بين الاقطاب على خصائص تفريغات بلازماالاركون لسبيكة Ti6Al4V

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الـخـلاصـة

يهدف هذا البحث إلى دراسة تأثير المجالات المغناطيسية الطولية بقوة (0 ,400 ،855)كأوس على جهد الانهيار لتفريغات غاز الاركون عند الضغوط الواطئة ولمسافات مختلفة(2،4،6،8) سم بين قطبي التفريغ الكهربائي. وقد أشارت النتائج المستحصلة لقياسات

منحنيات باشن إلى أن جهد الانهيار يتناقص بوجود وبزيادة المجال المغناطيسي المسلط.كذلك اشارت النتائج ايضا الى نقصان جهد الانهيار مع زيادة المسافة بين قطبي الكاثود لسبيكة Ti6Al4V وقطب الانود لسبيكة الحديد المقاوم للصدأ316L. ويستنتج إلى أن الانهيار للتيار الكهربائي المستمر لغاز الاركون يسهل إذا تم تطبيق مجال مغناطيسي طولي على طول محور التفريغ.

1. Introduction:

A glow discharge is produced by applying an electric potential across to plane electrodes with gas sample placed between them under vacuum [1,2]. Which is a common plasma source that can used to reinvestigation on behavior of ionization of neutral gas at some conditions like applied voltage and gas pressure [3,4].Glow discharges are used in many field, such as plasma etching, deposition of thin films, fluorescent lamps, flat plasma panels and light emission spectro-analysis[5-7].In breakdown the gas convert from an insulator to a conducting state. The minimum voltage leads to this change is called the break - down voltage (V_B). Study the electrical breakdown has a great interest for used in many devices such as in electronics and technology [8]. Paschen curves study the relation between breakdown voltages against pd. The minimum appears at some intermediate pdvalue. The breakdown voltage being high at low pd values as a result of the high voltage needed to gain more ions and electrons. Also V_B has high values at high pd values as a result of increasing collisions. V_B have been studied for different gases and identified with Paschen's curve. It has been found that the breakdown voltage and its minimum pd depend on gas sample, cathode material and its impurity[9].

The breakdown voltage V_B,is the minimum required voltage to start discharge across gas sample. Paschen has found experimentally the relation between gas discharge breakdown voltage with the product (Pd), following is the Paschen law expression of Townsend discharge [10,11].

$$V_B = \frac{Bpd}{\ln[Apd/\ln(1+\frac{1}{\gamma})} = f(pd) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..(1)$$

2. Experimental Work:

Fig.1 shows a diagram for main dc magnetron system parts used in this work, and the magnetron with closed-field which used near cathode. The vacuum chamber made of glass, was used with length 35 cm and diameter 14.5 cm. stainless steel disks, of 7.25 (cm) diameter and 0.4 cm thickness, were used as two electrodes. Two concentric ring magnets were placed behind cathode to form the magnetron shape as shown in Fig.2. DC power supply was applied on the electrodes to supply the system the needed power for discharge. The distance between two electrodes can be varied by moving the adjustable electrode (anode) vertically and with fixing the position of the upper electrode (cathode). The used sample gas was argon gas. A dc power can supply 3 kV was used for electrical discharge between the electrodes and both breakdown voltages and discharge current was watched by two digital voltmeter and ammeter, respectively. 6.8 kΩ resistor used as a current limiting across the discharge circuit to control the flowing circuit current. The chamber was evacuated by a two stage rotary pump with speed (16 m^3/h) at atmosphere. The vacuum inside the chamber was adjusted by needle valve and noticed by pirani gauge connected with chamber from ZDZ-52.

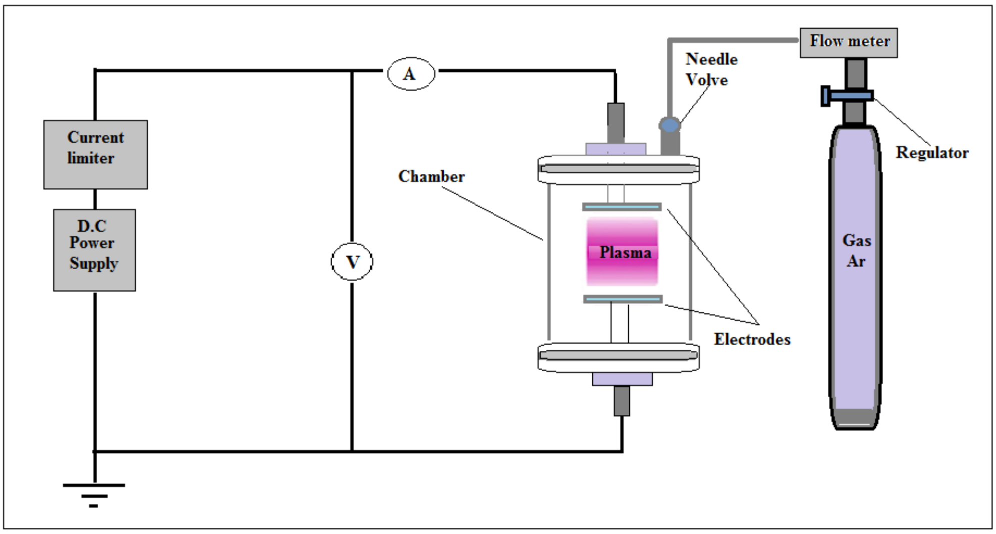

Fig.1: Schematic diagram for magnetic sputtering system.

Fig.2:(a) The dc magnetron plasma set-up ,(b) plasma produced between the two electrodes.

3. Results and Discussion:

Fig.3 shows the breakdown curves for argon measured with different inter-electrode spacing (2,4,6,8) cm . At low pd values the ionizing collision frequency is lower because the average length of electron trajectory is longer, i.e its need a higher voltage to sustain the required ions number to generate a continuous electrons flux to start a self-sustained discharge. At higher pd values, the mean free path of electrons being shorter, the electron energy increase between two collisions is lower, i.e. voltage with higher value is required to sustain enough ionization energy [7]. It can be seen from this figure that the increasing the inter-electrodes distance d Leeds to increase breakdown voltages and shift in the pd values. Table(1) shows the minimum breakdown voltage (V_B)min and (pd)min at different distance between cathode and anode for argon gas. It can be noted that increasing d near and to the right of the minimum and leads to the increase of (V_B). The shift of the breakdown curves to higher (V_B) and pd values with the increase of the inter electrode gap is due to the evolution of the charged particles diffusion to chamber wells [9].Note that the breakdown voltage increases with distance from (2 to 8) cm at constant pressure (0.5 mbar)and 40 sccm flow rate as shown in Fig.4.

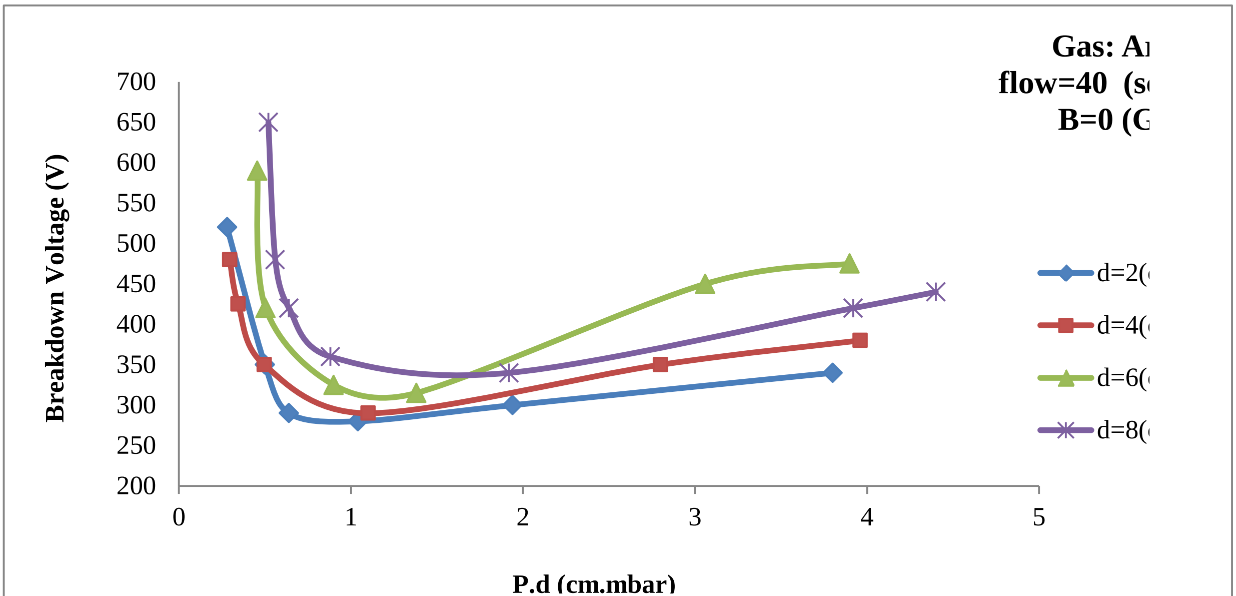

Fig.3: Paschen's curves of theAr gas discharge plasma at different d, without the effect of the magnetic field.

Table (1): Minimum breakdown voltage and pd minimum for Ar gas at different d distance without magnate field.

d (cm)	2	4	6	8
Breakdown voltage(V_B)min	280	290	315	340
P.dmin(mbar.cm)	1.04	1.1	1.38	1.92

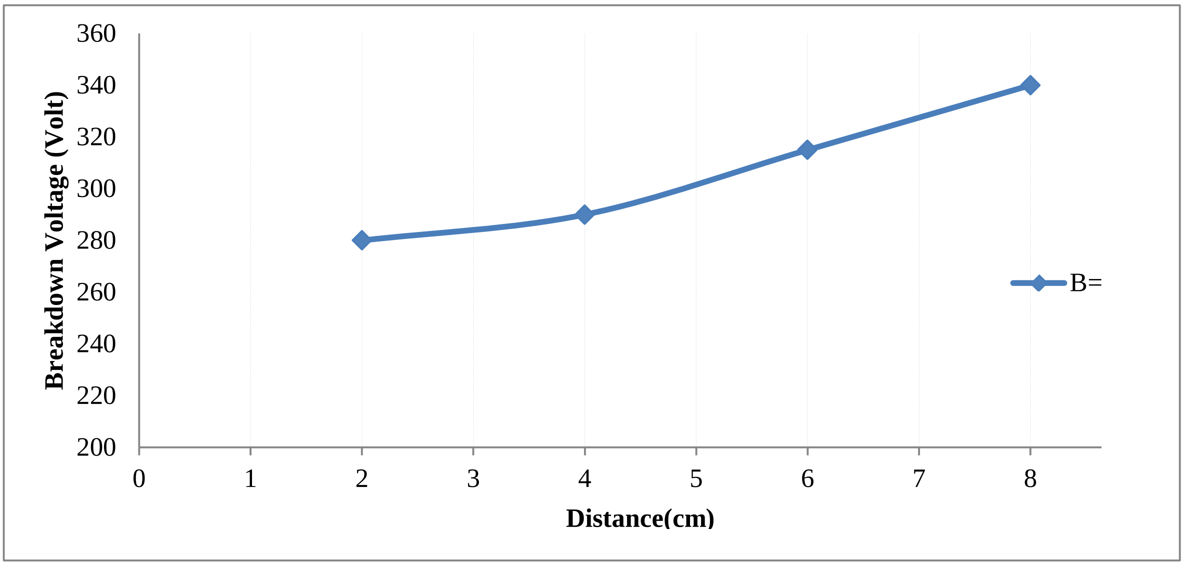

Fig.4: The variation of Breakdown voltage with distance between two electrodes at with magnetic field Gauss.

Fig (5) shows the variation V_B of Ar as a function of (pd), at the distance between the electrodes (4.5 cm) for various magnetic field strength(B). The results show a high influence of magnetic field, at low pressures. The $V_{B\ (min)}$ reduce from 280 to about 200 Volt with increasing magnetic field from (0 to 855) gauss. The $(pd)_{min}$ shift to lower values when magnetic field increases, and at higher pressures the magnetic field effect decrease. The effect magnetic field on a glow discharge like the effect of gas pressure increasing [8], i.e increase of$(V_B)_{min}$ with increase B. At low pressures the magnetic field being more efficiently for, because the decreasing of collisions due to pressure decreasing, cause enhancing the effectiveness of the magnetic field. The magnetic field lengthened the electron free paths and also the reduce of electrons diffusion toward walls, thiscan make more collisions for electrons with the gas molecules than at the absence of the magnetic field. Ions produced near the cathode are more efficient to produce secondary emission from cathode because more ions attack the cathode[9] .Table (2) shows the minima pd and breakdown voltage for argon gas at different magnate field strength near magnetron center.

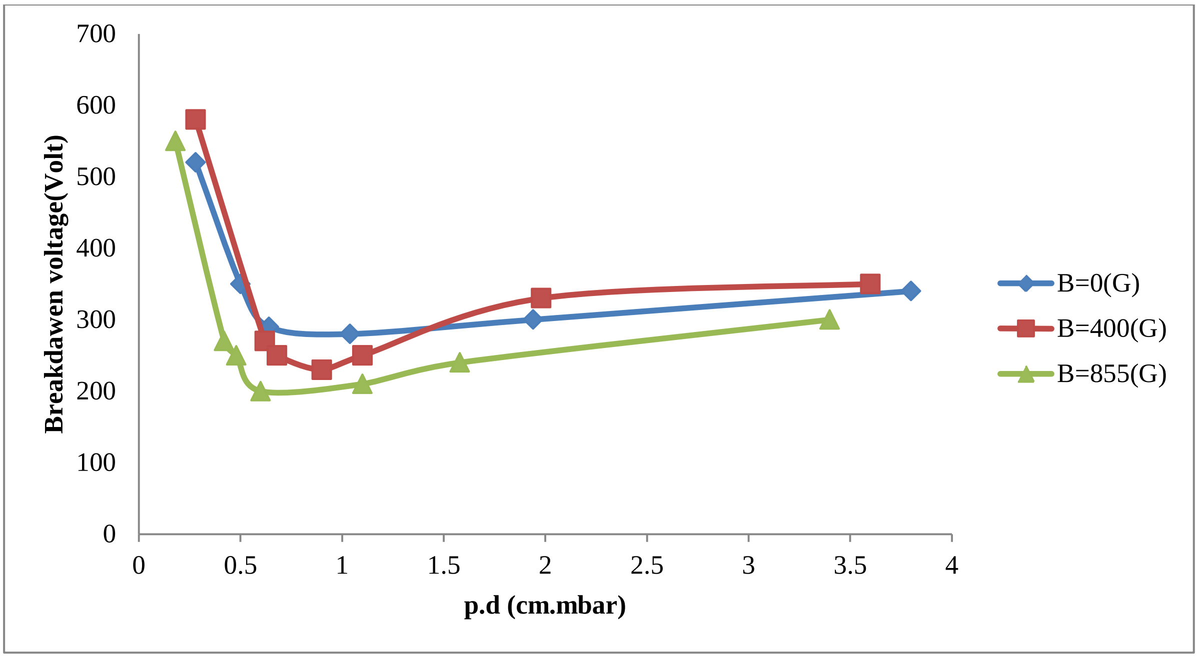

Fig.5:Paschen's curves of the plasma discharge at inter-electrode distance 2 cm and different magnetic field (0,400,855) Gauss.

Table (2): Breakdown voltage and the pd parameter for argon gas discharges .at affront magnate field strength.

	d=2 cm B=0 (G)	d=2 cm B=400 (G)	d=2 cm B=855 (G)
Breakdown voltage(V_B)min	280	230	200
P.d_{min}(mbar.cm)	1.04	0.9	0.6

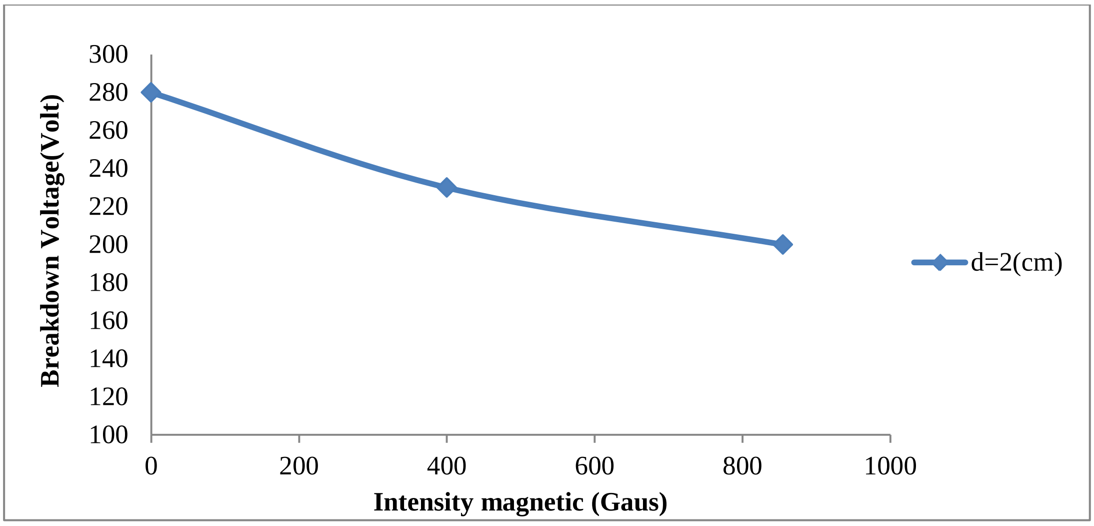

Figure (6): The variation of breakdown voltage with intensity magnetic field strength.

4. Conclusions:

The main results of this work can be summarized as follows:

- The breakdown voltage increases as the inter-electrode distance increased at the range (2-8) cm.
- Using magnetron caused to reduce the breakdown voltage and pd minimum as a result of increasing electrons mean path and reducing the diffusing from wall because the magnetic confinement.

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