International Journal of Recent Research and Review, Vol. V, March 2013

ISSN 2277 – 8322

Electrical Discharges Characterization of Planar Sputtering System

Bahaa T. Chaid[1], Nathera Abass Ali Al-Tememee[2], Mohammed K. Khalaf[3], Fwad T. Ibrahim[4]

[1]*Department of physics, College of Science, Baghdad University, Iraq*

[1]dr.bahaa2011@yahoo.com

[2]*Department of physics, College of Science, Baghdad University, Iraq*

[2]nathera_2007@yahoo.com

[3]*Ministry of Science and Technology, Baghdad, Iraq*

[3]mohammedkhkh@yahoo.com

[4]*Department of physics, College of Science, Baghdad University, Iraq*

[4]Fuadtariq2002@yahoo.com

Abstract- A home-made dc sputtering is characterized by cathode potential of 250-2500 V and sputtering gas pressures of (3.5×10^{-2} – 1.5) mbar. This paper studies in experiment the breakdown of argon, nitrogen, and oxygen in a uniform dc electric field at different discharge gaps and cathode potentials. Paschen curves for Argon, Nitrogen, and oxygen are obtained by measuring the breakdown voltage of gas within a stainless steel vacuum chamber with two planar, stainless steel electrodes. The Paschen curves in Ar, N_2, and O_2 gases show that the breakdown voltage between two electrodes is a function of *pd* (The product of the pressure inside the chamber and distance between the electrodes). Current-voltage characteristics visualization of the discharge indicate that the discharge is operating in the abnormal glow region.

Keywords: gas discharge, glow discharge, plasma , dc-sputtering.

I. Introduction

Dc glow discharges are widely applied for depositing thin films, etching, plasma polymerization, oxidation, and pumping gas discharge lasers, etc. Therefore the research into the conditions of the dc glow discharge is of considerable interest [1]-[6]. Plasmas are ionized gases; hence, they consist of positive (and negative) ions and electrons, as well as neutral species. Therefore, the ignition of the dc glow discharge is one of the oldest problems in the study of low-pressure gas discharges. The mechanism of the gas discharge can be explained as follows: When a sufficiently high potential difference is applied between two electrodes placed in a gas, the latter will break down into positive ions and electrons, giving rise to a gas discharge [7-9].

The field of gas discharge plasma applications has rapidly expanded in recent years. This is due to the large chemical freedom offered by the non-equilibrium aspects of the plasma [10-11]. This wide variety of chemical non-equilibrium conditions is possible, since (external control) parameters can easily be modified, such as: the chemical input (working gas; this defines the different species in the plasma: electrons, atoms, molecules, ions, radicals, clusters); the pressure (ranging from about 0.1 Pa to atmospheric pressure; as mentioned higher pressure typically reduces the collision mean free path, enhances the confinement and pushes the plasma toward equilibrium); the electromagnetic field structure (typically externally imposed, but it can also be modified by the plasma species; these electric and/or magnetic fields are used to accelerate, heat, guide and compress the particles); the discharge configuration (e.g. with or without electrodes;

discharge volume: a small volume typically means large gradients and thus departure from equilibrium). The temporal behavior (e.g. pulsing the plasma).

Because of this multi-dimensional parameter space of the plasma conditions, there exists a large variety of gas discharge plasmas, employed in a large range of applications.

This paper reports the results of homemade low-pressure plasma system where it can be used to enhance repeatability of the sputtering process. Experimental study of breaking down of argon, nitrogen and oxygen in the dc electric field in cylindrical discharge vessels with various inter-electrode gaps *d* and gas pressure supply were tested. Mechanisms and characteristics of plasma source are analysis as paschen characteristics curve, pressure-discharge current curves and discharge current-applied voltage.

II. EXPERIMENTAL WORK

The plasma system is made of a stainless steel cylinder (inner diameter *30 m*, height *34 m*), closed by stainless steel plates and sealed by o-rings. The electrodes and the metallic rods are encapsulated in Teflon shell so that only the electrode surfaces are in contact with the gas and edge effects are avoided. The shells used to cover the electrodes have a circular open area of $78.5\ cm^2$, which is the effective surface area of the electrode in contact with the gas. The electrodes are made of stainless steel of *15 mm* in thickness and*100 mm* in diameter. Before each experiment the electrodes are mechanically polished and chemically cleaned in dichloromethane. The pressure is controlled by a manual throttle valve mounted between the reactor and the pumping unit. The pumping system is composed of a rotary vane pump and a diffusion pump. The gas through put is set at 150 cm^3/s by a gas flow-controller. Different gases used for the experiment with purity of 99.99 %. Before each measurement the reactor is brought to a base pressure of about $3 \times 10^{-5}\,mbar$. A high voltage dc-power supply is used for delivering 3KV between two electrodes (see figure 1).

III. RESULT AND DISCUSSION

Planar parallel electrodes used to measure Paschen curves for different inter-electrodes spacing. We measured the breakdown curves of the glow discharge in argon, nitrogen and oxygen within the range of dc voltage $V_{dc}(250-2500V)$ and pressure of $8\times10^{-3} \rightarrow 1.5 mbar$ .Electrodes were employed and before taking measurements the cathode surface was purified by igniting the dc glow discharge in argon at a pressure of $8\times10^{-3} mbar$ and a discharge current $I_{dc} = 5-8$ mA for 10 min. Under these conditions the ion flux on the cathode is sufficiently large enough to remove the monolayer of gases remaining on the cathode surface after mechanical machining and polishing, but the discharge current value is not yet sufficient to produce the cathode spots that erode the cathode surface. Fig.2 and Fig.3 shows the paschen curves for argon, oxygen and nitrogen, which are obtained discharge tubes of fixed radius *R* and different inter electrode gaps *d*. It follows from these figures that on increasing the gap *d* the curves are shifted not only to the region of higher breakdown voltages U_{dc} , but simultaneously to higher *pd* values. However one can see from the results in Fig.3 that on increasing *d* the breakdown curves are also shifted to higher *pd* values .Consequently, the deviation from Paschen's law that we have observed is supported by the measured data of other authors [5,11]. In all probability, this shift of the breakdown curves to higher U_{dc} and *pd* values with the increase of the inter electrode gap *d* is associated with the growth of the losses of charged particles on the lateral walls of the discharge chamber due to the diffusion across the electric field.

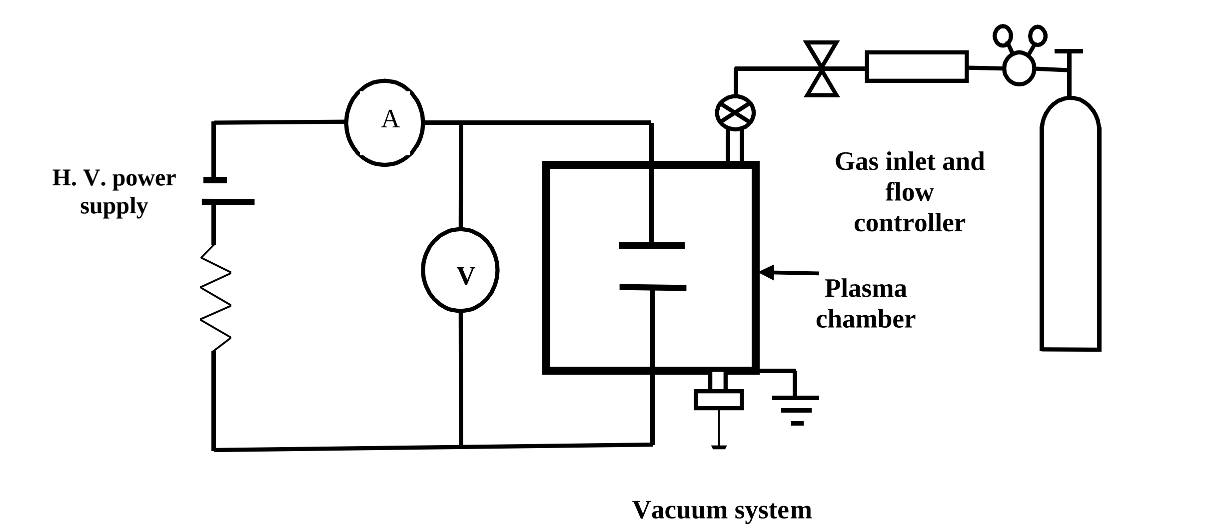

Fig. 1: Schematic diagram of the Low pressure plasma system.

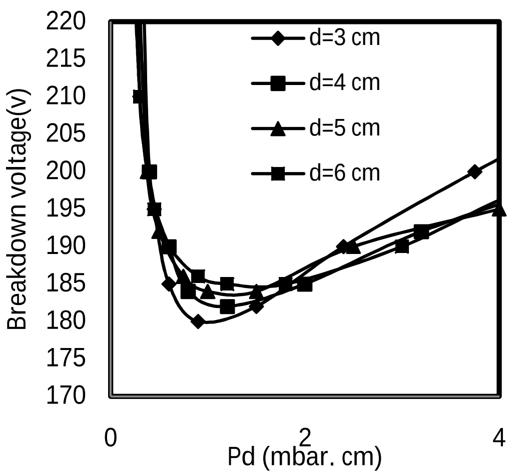

Fig.2: A plot of breakdown voltage of Ar as a function of pd with different inter-electrode spacing

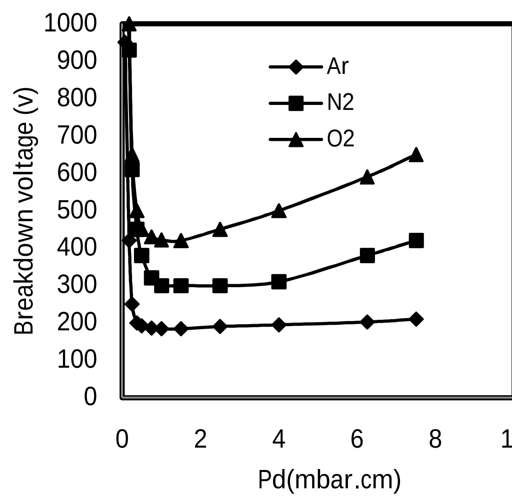

Fig.3: A plot of breakdown voltage as a function of pd with different gases for inter electrode spacing d=5cm.

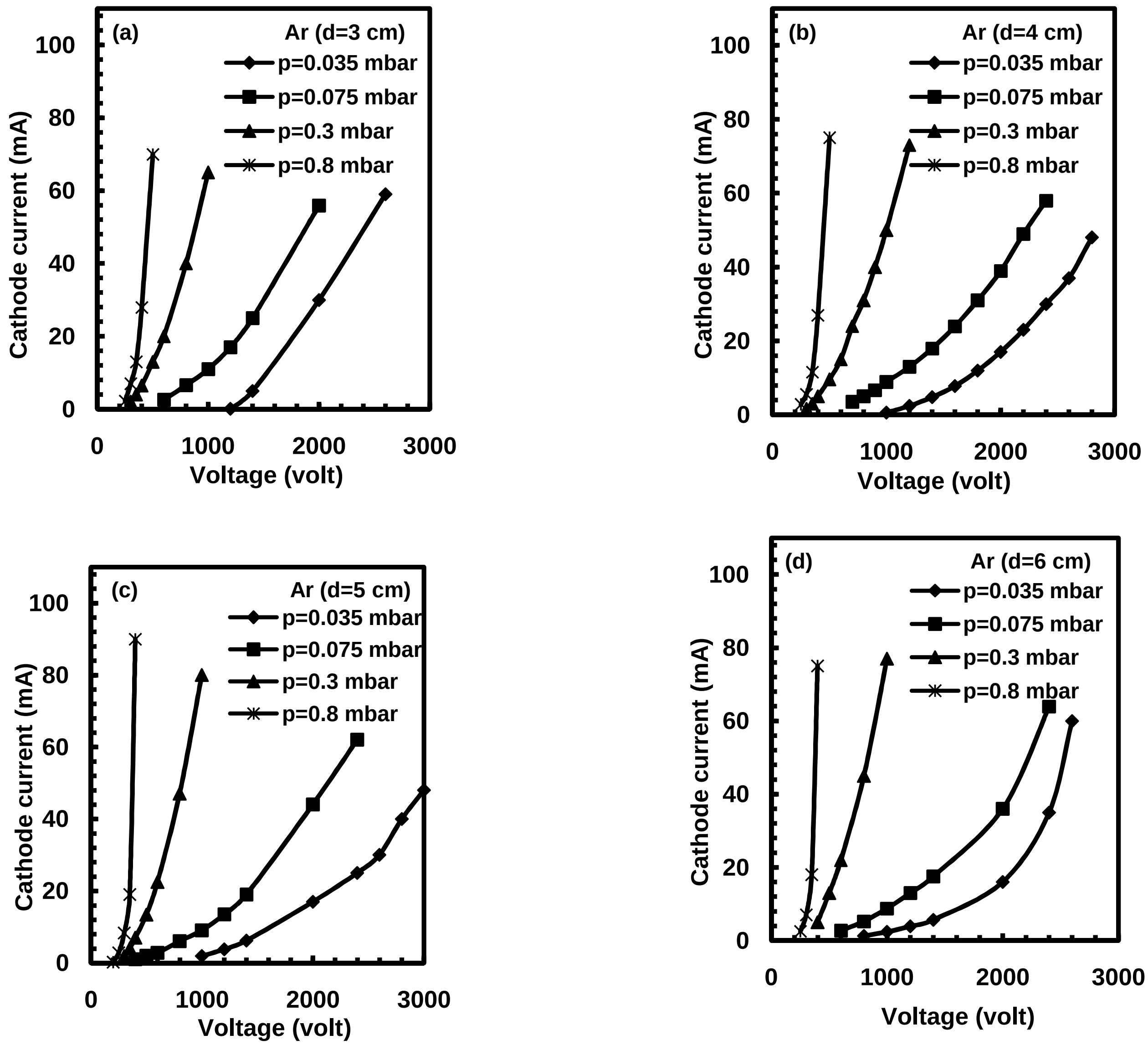

Fig.4: I-V characteristics of Ar discharge plasma at different value of gas pressure and inter-electrode spacing

The characteristics of glow discharge cathode current as a function of applied voltage for different argon gas pressure with different inter-electrode spacing have been established with the scheme shown in fig.4(d=3,4,5,and6 cm).The current in the external circuit can be measured as a function of voltage drop between the anode and the cathode. A further decrease in the external current limiting resistance brings the voltage /discharge current characteristic in to abnormal glow discharge region. This agrees with the data of [6] and also follows from the results of previous works [5]. Since the visible glow already covers the entire work surface, an increase in current density will now be accompanied by an increase in the voltage drop through the resistance of the glow discharge. These positive characteristics and behavior attributed to the mobility limited version of the child-Langmuir equation, where the current density is proportional to V^2 and inter-electrode spacing (d) [7].

Fig. 5 shows the dependence of cathode currents to the variation of working pressure using different type of gases with (d=5cm) and a constant applied voltage (700V). The cathode current increased gradually with increasing pressure of Ar,N_2, and O_2 to maximum value of cathode current at pressure equal 1.5, 1 ,and 0.8 mbar respectively. The decreasing of discharge current with high value of working pressure attributed to reduce the mean-free path of gas discharge electrons resulted to the increasing of electron-neutral collisions. It is also clear from the previous obtained figures that the maximum discharge current was obtained at an optimum inter-electrode spacing and pressure are equal to 5 cm and 0.8 mbar where the expected sputtering yield is maximum due to the increase of the output charge particles of glow discharge plasma.

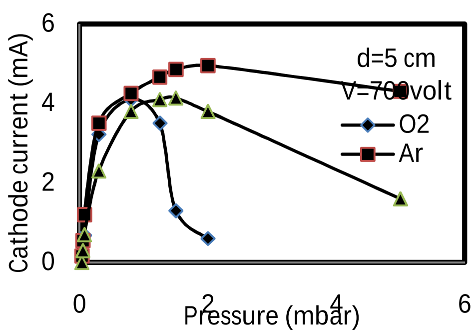

Fig.5: *I-P* characteristics for different gases plasma with biasing voltage (700volt)

IV. CONCLUSIONS

This home-built dc- sputtering system has long stable operation using nitrogen, argon, and oxygen gases. The present investigations show that an increase of the discharge voltage was accompanied by an increase of the discharge current, where the characteristics of such discharge is characterized by abnormal glow discharge. This dc-glow discharge system can be used for sputtering application.

V. REFERENCE

[1] Ed. Marcus, R. K. Pleunm, "*Glow Discharge Spectroscopes*", Press, New York, 1993.

[2] Bogaerts, A., et al, "Glow discharge modeling: from basic understanding towards applications", *Surf. Interface Anal.* 35, 593–603(2003).

[3] Speranza, A., et al, "Glow discharge in low pressure plasma PVD: Mathematical model and numerical simulations " *Meccanica*. 46, 681–697(2011).

[4] F.F. Chen, Plasma physics and controlled fusion, 1, Plenumm press, (New York), 1985.

[5] B. T. Chiad, T. L. Al-Zubaydi, M. K. Khalaf, A. I. Khudiar, *Journal of Optoelectronics and Biomedical Materials* ,1(3),255-262(2009).

[6] B. T. Chiad, T. L. Al-Zubaydi, M. K. Khalaf, A. I. Khudiar,*Indian J pure & Appl phys*, 48,723-730, (2010).

[7] A.Von Lnger, Ionized gases, (Uarenaon, Oxford), 1965.

[8] Meek J. M. and Craggs J. D. 1953 *Electrical Breakdown of Gases* (Oxford: Clarendon)

[9] Brown S. C. 1959 *Basic Data of Plasma Physics* (New York: Wiley)

[10] V. A.Lisovskiy, S D Yakovin and V D Yegorenkov, "Low-pressure gas breakdown in uniform dc electric field" ,*J. Phys. D: Appl. Phys.*33, 2722–2730 (2000).

[11] Annemie Bogaert, Erik Neyt, Renaat Gijbel, Joost van der Mullen, *Spectrochimica Acta Part* B 57, 609–658 (2002) .