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Study of the Effect of Cathode Graphite on I-V Characteristics of Argon DC Glow Discharge

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***Abstract*— In this paper, the electrical properties of the glowing Argon discharge were studied for the purpose of knowing the parameters of the stable plasma work. The Argon plasma generated from the DC glow discharge has been examined. The glowing discharge system consists of two electrodes , The cathode is made of graphite with a disk of 8cm diameter and 1.7cm thickness. The anode is made of aluminum material with a disk of 8.8cm diameter and 1.1cm thickness. The electrical electrodes are enclosed in a glass cylinder made of pyrex containing argon gas.**

Several parameters which affect on the state of electric discharge, including gas pressure and the distance between electrodes.(I-V) curves of electrical discharge were measured at different pressures(0.075,0.32,0.65,0.75 and 1.12 torr) and distance between electrodes(2,4,6 and10 cm). By observing the electrical properties (I-V), it is concluded that the electric discharge of the plasma argon gas works within the abnormal glow area and is an important parameter in the deposition process. The higher discharge current of the argon plasma increases with increased pressure, the higher deposition rate was achieved.

Keywords— Glow discharge, Graphite cathode, Plasma parameter.

I. INTRODUCTION

Glow discharge under low pressure is of great importance in many technological applications such as plasma light sources and the use of plasma to modify surfaces (1) and deposition of film (2). When a certain external voltage is applied to the gas, the electrical breakdown of the gas occurs and the electrons gain energy, which increases their velocity Collisions occur between electrons, ions, atoms or molecules. The collision of electrons with the atoms or particles and ions are a elastic collision because of the small mass of the electron and thus the energy reserved to electrons (3) .

The occurrence of an electrical breakdown and the generation of plasma at low temperature in various gases under low pressure is one of the most important processes to be applied in many practical applications. When the collision occurs power and discharge of the active and neutral active species are generated and their initial concentrations are dependent on pressure, gas type in the tube, glow current and glow time. When the electric discharge occurs, it is formed reassembly and removal operations on the cathode electrode leading to the emission of secondary electrons that are very important in the occurrence of collapse right (4) .

The electrical breakdown occurs when the electric field exceeds some of its critical value. As a result of collapse, various types of plasma are generated, although disassembly mechanisms can be very complex. But, generally, they usually start with the electron drift (5).

Ionization involves the creation of free electrons from atomic structure bonds, and they are generated in many ways of collisions and radiation. The effectiveness of ionization depends largely on gas pressure. Variable pressure refers to the random thermal energy of particle movement, where ionization energy increases at low pressure. The understanding of ionization depends on understanding the quantitative model of the atom.

In this model, the electrons are stable in the envelopes with different energies where the electrons in the outer casings are associated with the nucleus are small so it is an easy Ionization of electrons in outer covers.

Ionization occurs when the electron acquires more energy than the energy of bonding with the atomic envelope. The electron can be added to this extra energy in several ways, such as when colliding with other electrons or with ions or with neutral atoms or particles or by radiation (6). The Child-Langmuir Act is widely used in many areas of physics, including knowledge of the relationship between the cathode current voltage and the applied voltages and the distance between the electrodes and its mathematical form : (7)

$$J_{cl}=\frac{V^{\frac{3}{2}}}{L^2}\,\frac{1}{9\pi}\sqrt{\frac{2e}{m}} \quad \text{--------------(1)}$$

Here, e is the charge on an electron , m is its rest mass,V is voltage applied, L is distance between the electrodes For convenience, the terms current and current density are used interchangeably. They refer to the current density denoted by J .

In general, the current density is directly proportional to the amount of energy applied between the electrodes:

$$J = k\frac{u^m}{d_{sh}^n} \quad \text{-----------------------(2)}$$

Where k, m , n are constants constants u energy applied , d_{sh} The distance between the electrodes or thickness of the sheath (7) .

There is a comprehensive empirical study aimed at investigating the effect of the cathode material, the gas used, the magnetic field and the amount of distance and its effect in the generation of plasma, where the cathode electrodes were used from aluminum, tungsten and graphite materials nitrogen and oxygen as oxygen and nitrogen are considered to be reaction gases. Reaction process with these two gases and the cathode surfaces, specifically the processes oxidation and nitriding which, thus, affect characteristics of plasma (8).

The use of cathode surfaces of different materials and the knowledge of the voltage and current curves have the important effect on the distribution and flow of ions and the current density. When the pressure of working pressure is reduced, the flow of ions and the current density are more homogeneous on the surface of the wall (9).

II. Experimental equipment

The cathodic discharge system of argon gas consists of two parallel electrodes, cathode circular disk (diameter 8 cm and 1.7 cm)from graphite and the anode is made of aluminum as a disk (diameter 8.8 cm and thickness 1.1 cm), the electrodes are placed in a glass cylinder (diameter 10cm, length 15 cm) and the figure (1.a) illustrates the diagram of the system used.

The external DC discharge system is operated after connecting the digital devices used to measure the voltage and the current. The vaccum system using a rotary pump (Trivac D 16 E), mass (24Kg) and vaccum speed ($16m^3/h$), Pirani Gauge (Edwards). The rated voltage is controlled by a DC power supply with continuous high voltage (0-3000V) and current of (0-500mA). The system is connected as in the figure (1.b) and it operates for half an hour till the pressure reaches (0.06 torr). We fix the distance between electrodes and, then, argon is pumped to the discharge space till the pressure reaches (0.072 torr). We apply applied voltage till we obtain glowing discharge. Applied voltage and current are recorded for different distances and pressures.

Figure1.(a) represents discharge unloading system Dc

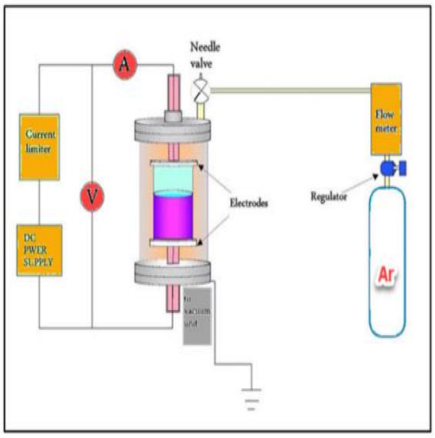


Figure 1. (b) illustrates the scheme for electric circuit

III. Results and discussions

Figure (2) (a, b, c, d) represents the characteristics of the DC glow discharge of plasma where the difference between current and voltage was examined at the distance (2,4,6 and10 cm) between electrodes. By choosing five pressures (0.075, 0.32, 0.65, 0.75and 1.12 torr), the results showed that the relationship between voltage and the current of the glow discharge is nonlinear, where the electrodes are completely covered by the glow discharge. The discharge area is within the part called "Abnormal glow" where the current is increased when increasing ($v^{3/2} /d^2$) is proportional to (I) voltage and this behavior is attributable to the discharge current (10). We also noticed that the discharge current of the Argon plasma increases with increased working pressure and the reason is that the free path rate is inversely proportional to the gas pressure, when the operating pressure is low. This means the free path rate of the electrons is relatively large as it is compared to the distance between the electrodes and therefore the number of ionized collisions decreases and electrons must acquire a lot of energy so that the ionization of the gas molecules occurs and then electrical breakdown takes place. This conclusion is compatible with the results that (11) obtained.

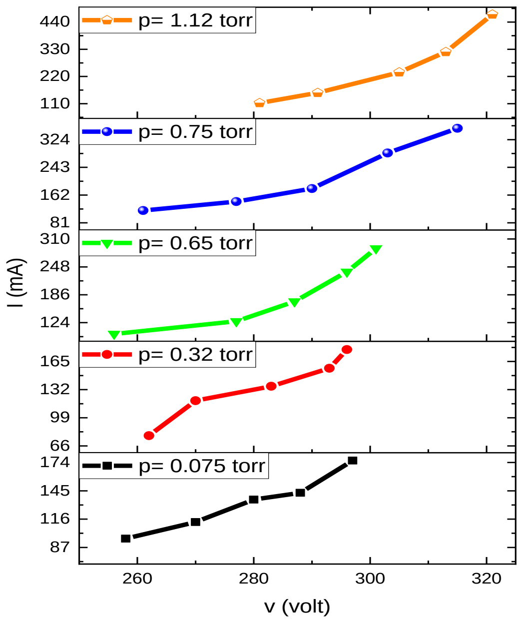


Figure (2a) Curved (I-V) at a distance of (2cm)

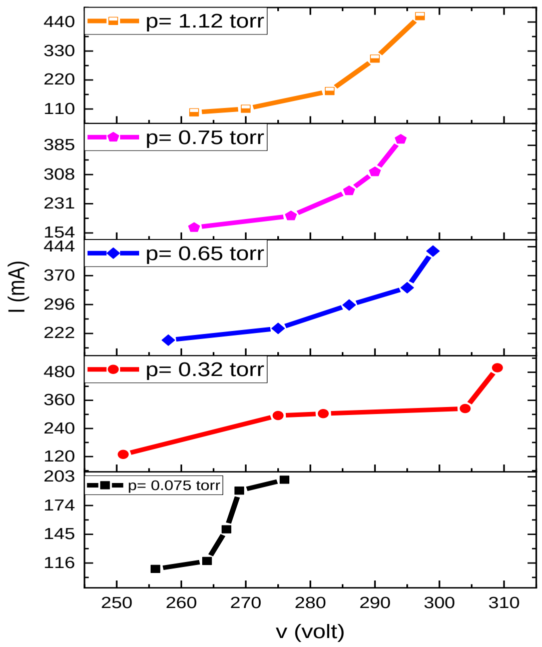
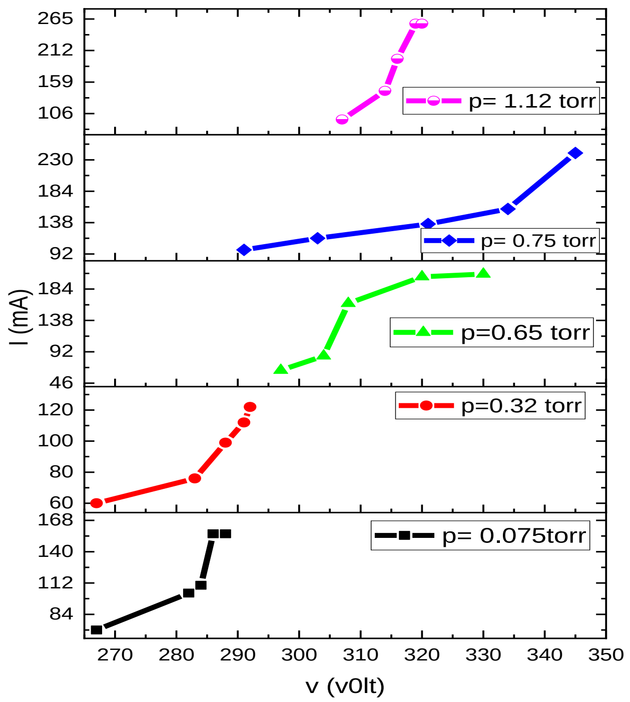


Figure (2b) Curved (I-V) at a distance of (4cm)



Figure(2c) Curved (I-v) at a distance of (6cm)

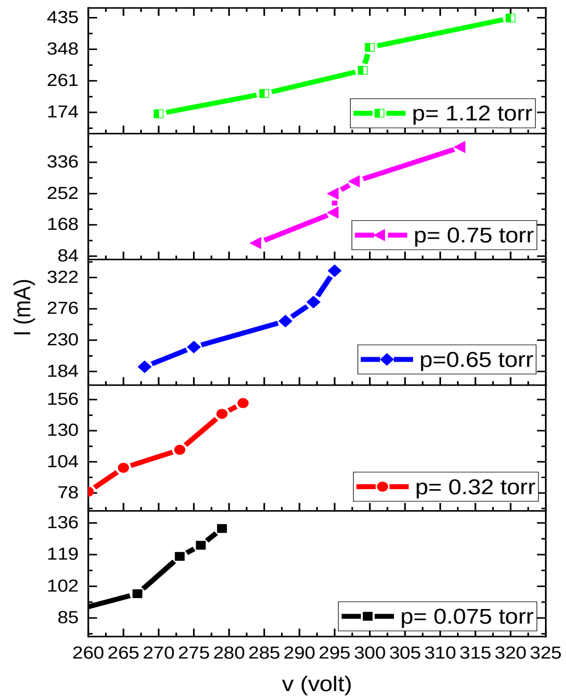


Figure (2d) Curved(I-V) at a distance of (10 cm)

In the case of increased operating pressure, the current increases. This can be explained as follows: when increased pressure leads to occurrence decrease in the free path rate of electrons and thus it leads to increasing in the number of collisions with the atoms or molecules of gas. This increase in the number of collisions requires greater voltage for the electrons to get ionization of the atoms or molecules of gas(13).

IV. Conclusions

Through the work, the results that can be concluded are as follows: Firstly, the electrical properties of the gas discharge indicates that plasma system to the argon gas operates within the abnormal ignition discharge area. This property has an important and essential effect in the manufacture of microelectronic materials. Secondly, when the voltage increases, the discharge current DC increases as well. In this case, the sedimentation process increases. Thirdly, it is observed through curves (VI) that the curve in nonlinear. This behavior is attributed to the discharge current (I) which is compatible to ($V^{3/2}/d^2$) .

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