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Research Article

STUDIES ON THE ELECTRICAL CHARACTERISTICS OF AN ARGON DC GLOW DISCHARGE

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ARTICLE INFOABSTRACT

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Electrical characteristics of a DC glow discharge are studied with the aim of determining the suitable parameters for stable operation of the plasma system. Argon plasma produced by DC glow discharge is investigated with a further goal of studying plasma phenomena, when addition a small amount of argon gas can significantly change the plasma characteristics. The discharge system has two disc-shaped parallel plate electrodes. The electrodes are enclosed in a large cylindrical glass chamber filled with argon gas. Two important physical parameters affecting the condition of the discharge are the gas pressure and the inter-electrode distance. The discharge current-voltage (I-V) characteristic curves of the discharge and Panchen's curves were measured at different working pressure and inter-electrode spacing, The Paschen curves in Ar gas show that thebreakdown 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. The I-V characteristics of argon gas discharge were deduced as a plasma system operated in abnormal glow discharge region, which is very important parameter in sputtering deposition. Also the discharge current was increased for argon plasma discharge with the increasing of the working pressure lead to increase the deposition rate.

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]. It is created by applying a potential difference between two electrodes that are inserted in a cell filled with a gas [2]. At normal temperature and pressure, the gases are excellent insulators [3]. Various phenomena occur in gaseous dielectrics when a voltage is applied. As the applied voltage is low, small currents flow between the electrodes, and the insulation retains its electrical properties. On the other hand, if the applied voltages are large, the current flowing through the insulation increases very sharply, and an electrical breakdown occurs [4].The physics of the electrical breakdown have a great significance because of its wide applications in electronics and technology. The electrical discharges in gases are of two types, i.e. (i) non-sustaining discharges, and (ii) self-sustaining types. The breakdown in a gas, called spark breakdown is the transition of a non-sustaining discharge into a self-sustaining discharge [5].

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The build-up of high currents in a breakdown is due to the process known as ionization in which electrons and ions are created from neutral atoms or molecules, and their migration to the anode and cathode respectively leads to high currents [6]. As mentioned above a glow discharge is formed by application of a potential between two electrodes. Depending on the pressure p of the gas and the distance d between the electrodes a breakdown voltage [7].

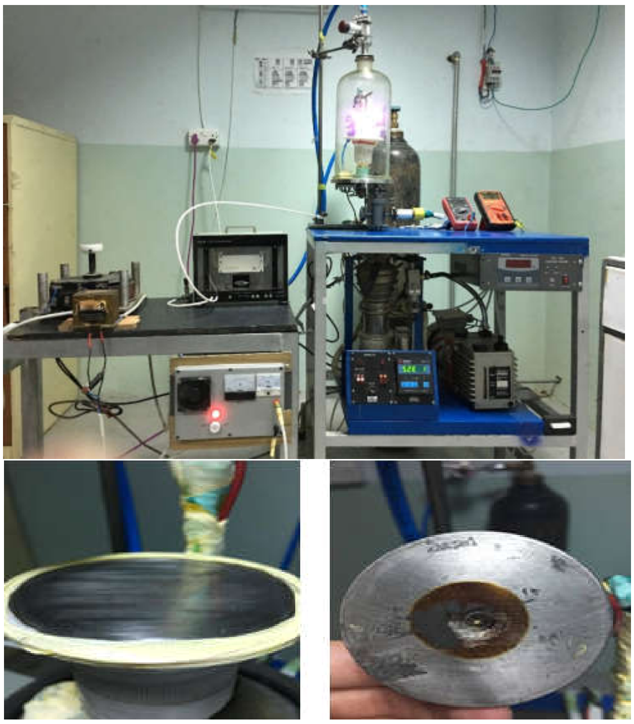
$$V_B = \frac{Bpd}{\ln[Apd - \ln(1+1/\gamma)]} \quad (1)$$

This equation is known as Paschen's law, Where V_B is the breakdown voltage P is the pressure and d is the gap distance. The constants A, B and γ(secondary electron coefficient) are constants (depend upon the composition of the gas).depend Depend upon the composition of the gas. This equation shows a relationship between V and pd, and implies that the breakdown voltage varies as the product pd varies.The relationship between V and pd is not linear and has a minimum value for any gas.

The existence of a minimum sparking potential in Paschen's curve may be explained as follows:[8] At low pd values before the Paschen's minimum, the average length of the electron trajectory is longer and the ionizing collision frequency lower. A higher voltage is needed to maintain the number of ions with the required energy to regenerate a continuous flux of primary electrons. In short, a higher voltage is needed to start a self-sustained discharge.For higher pd values, the mean free path of electrons is shorter and collisions more frequent. However, the electron energy increment increase between collisions is lower.

EXPERIMENT

The DC glow discharge system consists of two parallel electrodes enclosed in a cylinder chamber. The two electrodes were made of glass with length 20 cm and 2mm diameter. A schematic diagram of the device used in this investigation shown in Figure (1). The discharge was operated in DC mode, the external resistance RL was used to limit the discharge current, to ensure that the discharge would be limited to the abnormal glow discharge region. And digital multi-meters was used measured the discharge current and the voltage. Basically, the inside of the chamber consists of two electrodes between which the glow- discharge is formed One of them is movable (denoted Anode) and the fixed electrode (denoted cathode) . And each of them was 10 cm diameter, he discharge chamber was evacuated using a two-stage rotary pump (Edward of 12 m3/h), and diffusion pump (Alcatl of 380L/sec) The gas flows controlled with flow meter as a gas flow rate of the gas mixture and the gas pressure was monitored by perani gauge with Edward's controller 1105. The applied voltage was controlled by a DC power supply which can produce potential up to 1400 volt.



(a) (b)

Figure 1. a photograph of the main experimental set-up used in this work: (a) cathode (b) anode electrodes

RESULTS AND DISCUSSION

The electrical characteristics of discharge plasma, such as dependencies of discharge current on the applied voltage and gas pressure inside the vacuum chamber as well as Paschen's curve, are of importance to introduce the homogeneity of the generated plasma. In the following, these characteristics arepresented. Infig. (1), the discharge current was measured as a function of dischargevoltage at different working pressure (0.055, 0.085, 0.11, and 0.25 mbar) for constant inter-electrode distance (d=4 cm). The current was differed by changing the dc power supply voltage. Electric field quickens the electrons and particles which then crash into molecules of gas bringing about to build discharge current and gas temperature. The discharge in our framework is worked in the abnormal region. In this mode all cathode surface is completely secured by the discharge and an rise of the current prompts an rise of the current density on the cathode surface, hence, to an increment of the voltage.

The outcomes demonstrate that the connection between current (I) and voltage (V) of a glow discharge is very non-linear, (i.e. Abnormal glow). The electrodes are completely secured by the discharge and further current rises prompts an increasing in the cathode fall. Therefore, the voltage over the electrodes rises pointedly. Fromfig. (1), we found that an increase of the discharge voltage was accompanied by an increase of the discharge current, where the characteristic of such discharge is characterized by abnormal 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 argon plasma discharge with the increasing of the working pressure , this can be explained as the following statement:The mean free path of a molecule in a gas is the average distance between the collision of molecule with other molecule. This is inversely proportional to the pressure of the gas. The accelerated electron will acquire more than enough energy to ionize an argon atoms. This liberated electron will in turn be accelerated which lead to another collision. A chain reaction then leads to avalanche breakdown 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]

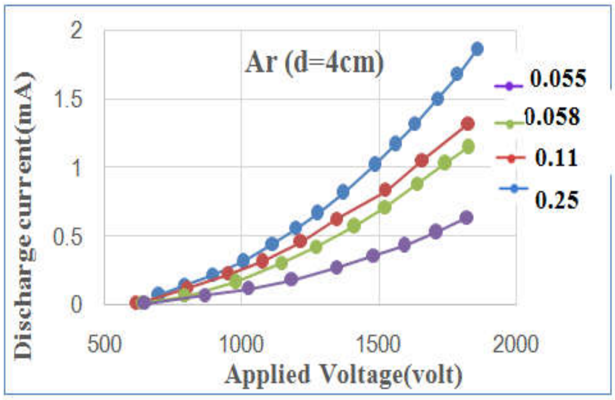


Figure (1): The variation of discharge current with discharge voltage at different working pressures (chamber pressure) of Ar gas at distance (d=4cm).

In the other hand figure (2), the Paschen's curve of argon gas was plotted at different inter-electrode distances (2-9 cm) in order to determine the point at which the sputtering process is applicable. As seen, in the left-hand side of the curve, the breakdown voltage increases with decreasing gas pressure and inter-electrode spacing. These results can be explained as a decrease in the collision frequency, at low gas pressure, the electron mean free path was longer and collision probability was less than that at high gas pressure, so there were few collisions.

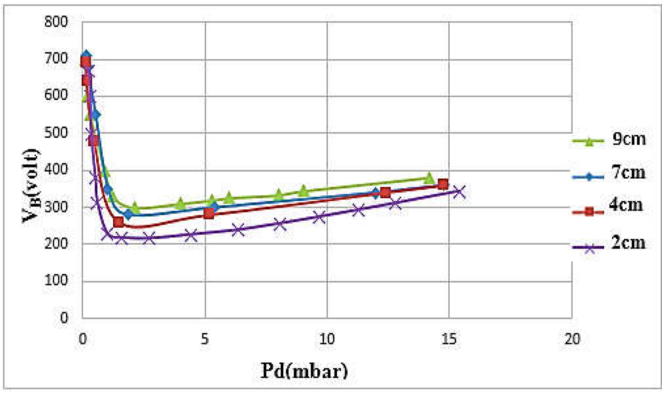


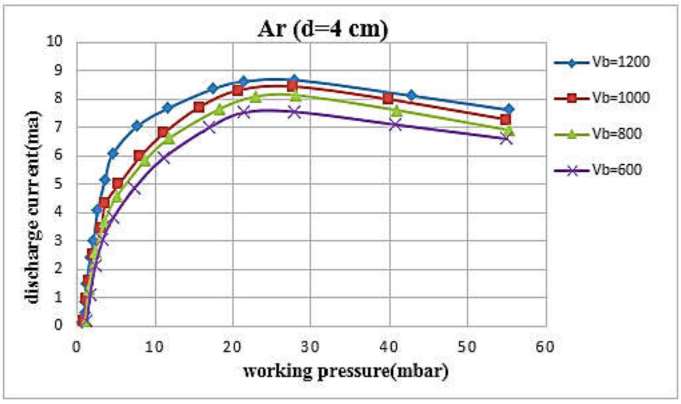
Figure (2): Paschen curves as function of inter –electrode spacing for Ar gas discharges.

There is low probability that any of the secondary electrons emitted can collide with neutral atoms during the journey from the cathode to the anode. In the right-hand side, the breakdown voltage increases slowly with the increase of gas pressure, i.e., the ionization cross-section increases, with the increase of *p.d* product. Therefore, electrons need more energy to ionize the neutral atoms. Tables (1) show the minimum breakdown voltage (VB)min and pdmin at different distance between cathode and anode for argon gas. This result depends on the collision cross-section of gas which related to secondary electron coefficient where, at increasing the size of the gas atoms/molecules the collision cross-section increased [11].

Table 1. Breakdown voltage as a function of *pd* parameter for argon gas

	d=2 cm	d=4 cm	d=7 cm	d=9 cm
Breakdown voltage(V_B)min	229	260	280	299
Pd_{min}(mbar.cm)	0.993	1.51	1.84	2.1

Figure (3) show the Ar gas discharge current as a function of working gas pressure with a constant inter-electrode spacing (d=4cm) for different discharge voltage. The discharge current was varied by changing the working gas pressure when the discharge current reach to maximum value and then decreases with increasing of gas pressure because the electric field accelerates of ions and electrons which then collide elastically with atoms/molecules of working gas giving rise to discharge current [12].With increasing of working gas pressure, which is attributed to more molecules which are available for the electrons to collide with and to generate a new free electron and a positive ion and so making the DC voltage more negative.



Figure(3): The variation of discharge current with working gas pressure for Ar gas.

Conclusion

This home-made dc-sputtering system has long stable operation using argon gase. 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.

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