Electrical Discharge Characterization of Planar Sputtering System for Gold Target

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Abstract

Before using any sputtering system, the extent of the operating pressures and voltages must be known by studying the breakdown curve with the product of the working pressure times the inter electrode distance. In this paper, argon breakdown by dc electrical potentials was experimentally studied. Paschen curves for argon gas were obtained by measuring the breakdown voltage of argon using gold target. These curves display that the breakdown voltage in Ar gas between two planer electrodes comparable with (P. d). The I-V characteristics of the plasma discharge point to that the discharge is working in the abnormal glow region.

Keywords: Dc discharge plasma, Gold target, Argon, Sputtering.

توصيف التفريغ الكهربائي لمنظومة الترذيذ باستخدام هدف من الذهب

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الخلاصة

قبل استخدام أي منظومة ترذيذ يجب معرفة مدى الضغوط والفولتية التي تعمل فيها من خلال دراسة منحنى فولتية الانهيار مع حاصل ضرب الضغط في المسافة بين القطبين. تم في هذا البحث عمل دراسة عملية لجهد الانهيار في غاز الأركون باستخدام مجال كهربائي مستمر. تم الحصول على منحنيات باشن لغاز الأركون عن طريق قياس جهد انهيار الغاز باستخدام هدف من الذهب. بينت هذه المنحنيات أن جهد الانهيار لغاز الأركون ان التفريغ الكهربائي بين القطبين المستويين يكون كدالة لـ (P. d) (حاصل ضرب الضغط داخل الحجرة في المسافة بين الاقطاب). بينت خصائص التيار - فولتية أن التفريغ يعمل في منطقة التوهج فوق الطبيعي.

كلمات مفتاحية: تفريغ البلازما بالتيار المستمر، هدف الذهب، الاركون، الترذيذ.

Introduction

Dc glow discharge is used in many fields such as thin films deposition, oxidation, and etching, etc. Optimization of dc discharge working parameters has significant attention [1,2]. In recent years, a great attention has been given to plasma applications due to the possibility of controlling plasma properties to deposit many complex chemical compounds.

This can be done by controlling the plasma parameters and materials introduced during the reaction, working pressure and electromagnetic field (which are used to accelerate and guide the particles) [3, 4]. Plasma is a quasi-neutral assembly of charged particles (ions and electrons) and neutrals. The burst of the dc glow discharge is one of the first complications in the gas discharges study at low-pressure. When a sufficient potential difference is applied between two electrodes placed in a gas, a flash occurs, and a large current passes and the gas behaves as a conductor. The transition from an insulating to completely conducting state is called the electrical breakdown [5, 6]. This paper illustrates the homemade plasma sputtering system results, with cylindrical shape vessels, and study its characterization to enhance the sputtering process.

Experimental Work

Plasma system was made of a stainless-steel cylinder, with 28 cm inner diameter and 35 cm height, sealed with rubber O-rings. The electrodes and the metallic rods are covered by Teflon so that only the planer electrode surfaces are exposed to the gas, with 8 cm diameter circular open area, to avoid edge effects. The anode is made of 10 cm in diameter stainless steel, while the used cathode is made of gold with purity of 99.99 %.

The electrodes were polished and cleaned thoroughly before each operation of the system. The pumping system consists of a double stage rotary pump and a diffusion pump. The pressure is controlled manually by controlling the gas that enters the chamber using needle valve and flow-controller. A high voltage dc power supply is used.

Result and Discussion

The I-V characteristics of dc glow discharge using gold target for argon gas at different pressures and different inter-electrode spacing (d) were illustrated in figure (1).

The current was varied with the change of dc power supply voltage by a fixed controller resistance. The discharge in our device is operated in abnormal regime which is characterized by a mutual increase/decrease of discharge voltage and current density, where the increase in voltage above the glow discharge regime causes the surface of cathode to be fully covered by discharge then leads to an increase in current density with voltage [7].

From these figures, one may observe that the current increased non-linearly with increasing pressure.

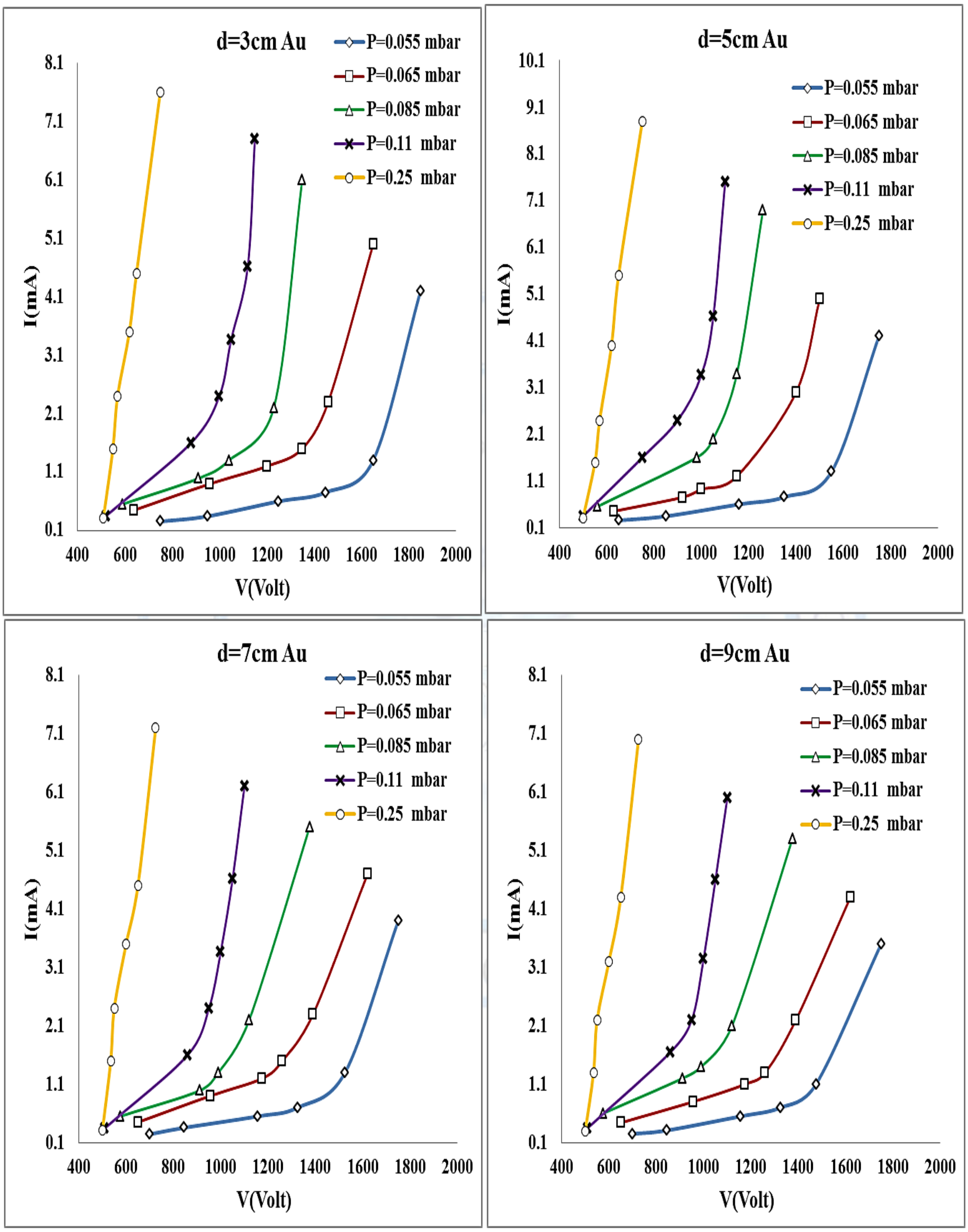

Figure 1: Variation of the discharge current in Ar gas with applied voltage using Au target at different working pressures

figure (2) shows the current-voltage characteristics of the dc glow discharge at constant pressure 0.055 mbar at different inter-electrode distances (3, 5, 7 and 9) cm for gold target. The current was varied by changing the dc power supply voltage with a fixed controller resistance. This figure shows that the increase in the voltage leads to an increase in the current density [8]. It can be seen that at 5 cm inter-electrode spacing, the discharge current becomes higher compared to other distances with same voltage.

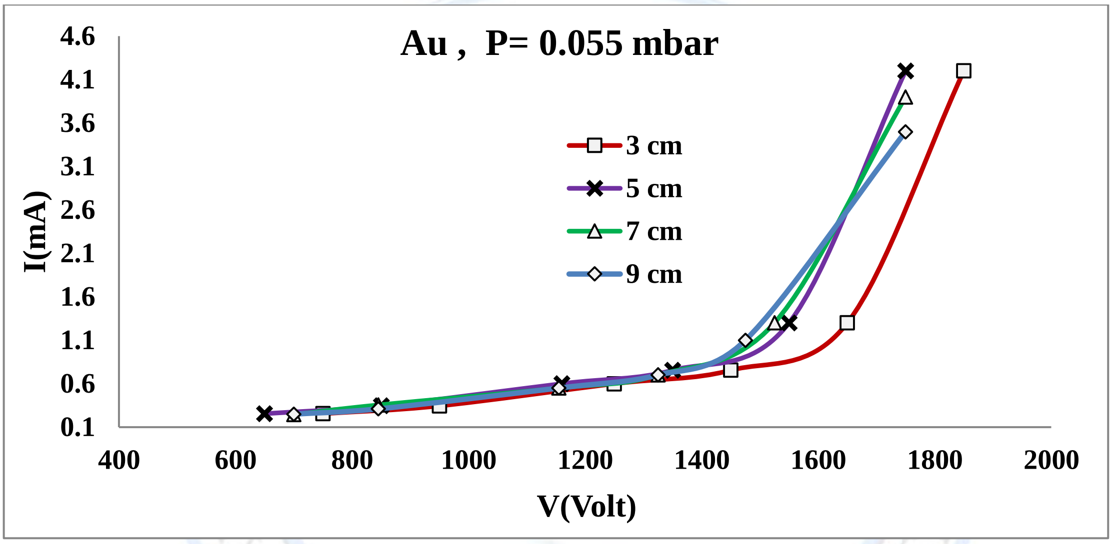

Figure 2: Variation of discharge current with applied voltage for different distances of Ar gas for Au target

The current-pressure characteristics of the dc glow discharge using gold target at constant inter-electrode spacing (d =5 cm) and constant applied voltage (V=1000 volt) for argon gas are presented in Figure (3). The current was varied by changing the working pressure with a fixed controller resistance. The current-pressure characteristics of argon gas discharge displays an increasing current with increasing the working pressure in chamber at constant supplied power to the system. This performance causes an increase in the produced ions and other particles in glow region, causing to enhance the secondary electron emission from cathode. The decrease in discharge current with high value of working pressure is attributed to reducing the mean- free path of gas discharge electrons resulted to the increasing of electron-neutral collision [9].

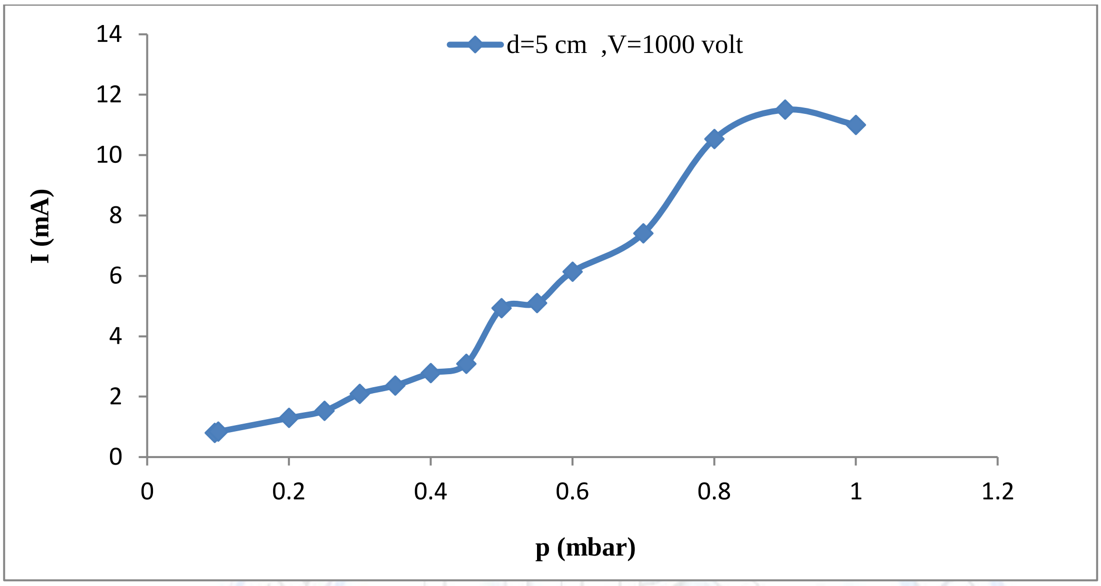

Figure 3: Variation of the discharge current with different working discharge pressures for the Au target at distance 5 cm

Figure (4) shows the breakdown voltage curves for argon, using Au target, measured with different inter-electrode spacing. At low p.d (on the left of the minimum breakdown voltage in Paschen's curve) the average electron path between two collisions with heavy species is longer, so the less ionizing collisions occur. More voltage should be supplied to create same number of ions and electrons which sustained the plasma.

At high p.d values, when the electron mean free path is shorter and electron-neutral collisions become more frequent, the energy of electrons becomes less, as electrons lose their energy by means of non-elastic collisions. Therefore, excitation reactions compete with ionization reactions and therefore require high potential to produce more ions. Moreover, at high pressure, the ion-free path becomes less, and the ions lose energy in the gas through elastic collisions, so a higher voltage is needed to maintain ion energy to cause the current to flow [11]. It follows from this figure that when increasing the gap d, the curves are shifted not only to higher breakdown voltages, but simultaneously to the higher p.d values. This shift of Paschen curves to the higher V_B and p.d values is associated with growth of the losses of charged particles on lateral walls of discharge tube as a consequence of diffusion across the electric field [12].

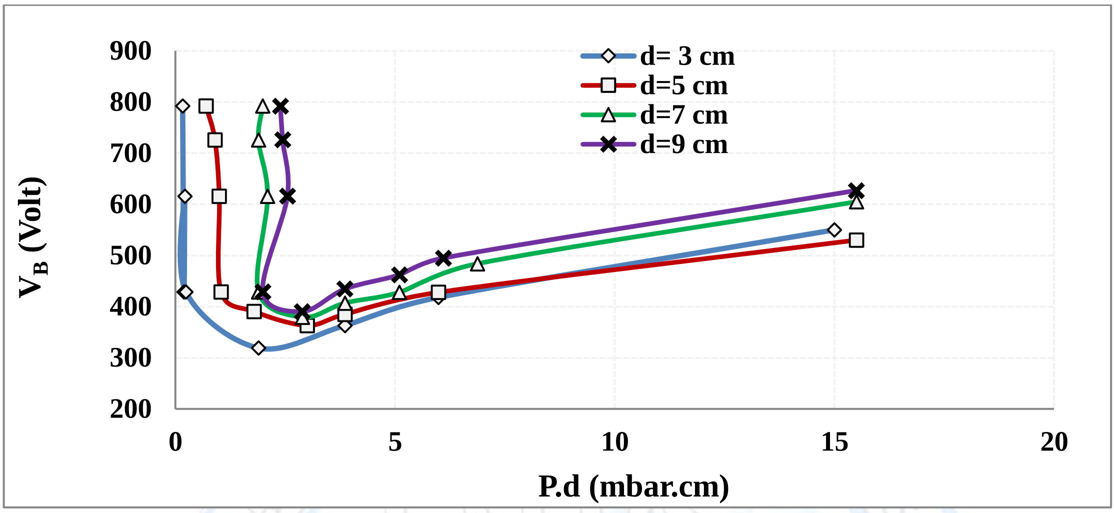

Figure 4: Paschen curves of the glow discharge in argon for the Au cathodes for different inter-electrode distances

Conclusions

Stable action homemade dc- sputtering system was made. The I-V characteristic shows a direct relation, i.e., increasing the voltage causes to increase the current that passes through the system. This means that the work is classified within the abnormal glow discharge region.

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