Electrical Discharge Characterization of Planar Sputtering System of different targets

Mohammed K. Khalaf[1], Sabri J. Mohammed[2*], Dawood Salman Ali[3], Mohammed J. Dathan[4*]

[1] Higher Education & Scientific Research, Baghdad, Iraq
[2,4 *]Department of Physics, College of Education, Tikrit University, Iraq
[3]University of Anbar-College of Education for pure sciences, Iraq

Abstract

A home-made dc sputtering system, which is characterized by cathode potential of 250-2000 V and sputtering gas pressures of (3.5×10^{-2} – 1.5) mbar. In this paper we have studied the breakdown of argon, the uniformity of dc electric field at different discharge gaps and finally the cathode potential. Paschen curves for Argon are obtained by measuring the breakdown voltage of gas With a different targets. (Au, Cu and Ag). The Paschen curves in Ar 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 indicates that the discharge is operating in the abnormal glow region.

Keywords: (Au, Cu and Ag) target , gas discharge, glow discharge, plasma, dc sputtering**.**

مميزات التفريغ الكهربائي لمنظومة الترذيذ المستوي للأهداف المختلفة

محمد خماس خلف[1] , صبري جاسم محمد[2*], داود سلمان علي[3], محمد جوير ديثان[4*]

[1]وزارة العلوم والتكنولوجيا- مركز بحوث التطبيقية, بغداد, العراق
[4,2*] جامعة تكريت - كلية التربية للعلوم الصرفة
[3]جامعة الانبار- كلية التربية للعلوم الصرفة

منظومة التفريغ صنع محلي مميزاتها هي جهد الكاثود من 250-2000 فولت وضغط غاز الترذيذ هو(3.5×10^{-2} – 1.5) ملي بارز في هذا البحث تم دراسة انهيار الاركون في مجال كهربائي مستمر منتظم مع اختلاف فجوة التفريغ وجهد الكاثود. منحني باشن للاركون تم ايجاده بقياس فولتية الانهيار للغاز مع اهداف مختلفة (ذهب, نحاس, فضة). منحني باشن لغاز الاركون يبين فولتية الانهيار بين القطبين (الكاثود والانود) كدالة ل Pd (هي حاصل ضرب ضغط الغاز داخل غرفة التفريغ P والمسافة بين القطبين d) مميزات التيار - الفولتية تشير الى ان العمل يحدث في منطقة التوهج فوق الطبيعية.

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]-[2]. 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 [3-4]. 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 [5-6]. 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). 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.

2. Experimental Work

The plasma system is made of a stainless steel cylinder (inner diameter *30 cm*, height *34 cm*), 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 cm2* 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 , as show in fig.(1). Before each experiment the electrodes are mechanically polished and chemically cleaned in dichloromethane. The pressure has been controlled by a manual throttle valve, which is 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 300 SCCM a gas flow-controller. Target used (Au,Cu and Ag) for the experiment with purity of 99.99 %. A high voltage dc power supply is used for delivering 2KV between two electrodes.

Fig. (1) The main experimental set-up used in this work.

3. Results and Discussion

The current-voltage characteristics of the dc glow discharge for different pressures and different inter-electrode spacing (d) for argon gas presented in Fig.(2to 4) for (Au, Cu and Ag). The current was varied by changing the dc power supply voltage with a fixed controller resistance. The discharge in our devices is operated in the abnormal regime. In this regime the cathode surface is fully covered by the discharge and an increase of the voltage leads to increase of the current density. The plasma behaves electrically rather similar to a resistance[7]. The work function has inverse relation with secondary electron coefficient. The values of work function for used metals are (ΦAu = 5.1 eV, ΦCu = 4.65 eV and ΦAg = 4.26 eV).

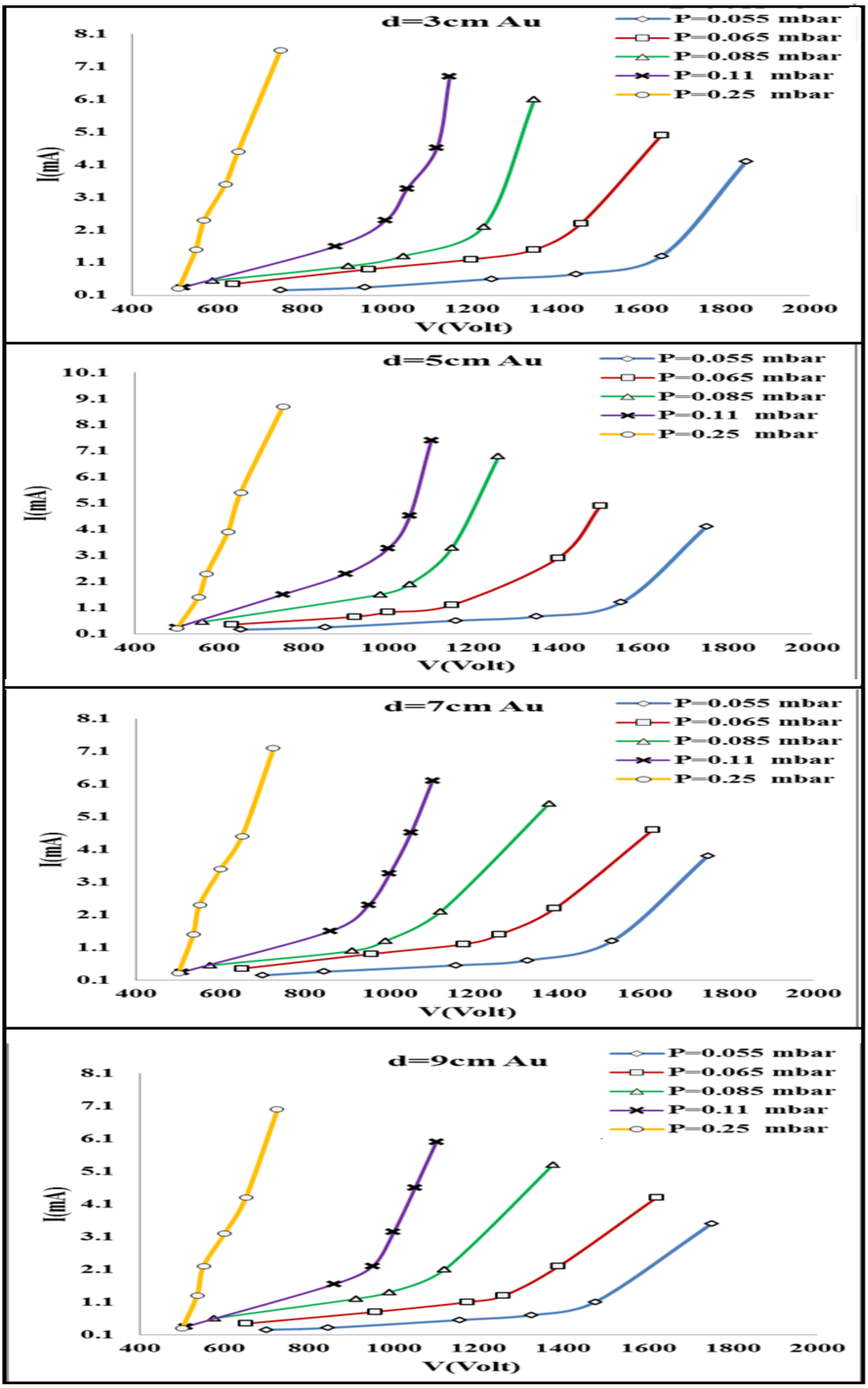


Fig.(2) The variation of discharge current with applied voltage at different working pressures of Ar gas for different inter- electrodes spacing using Au target.

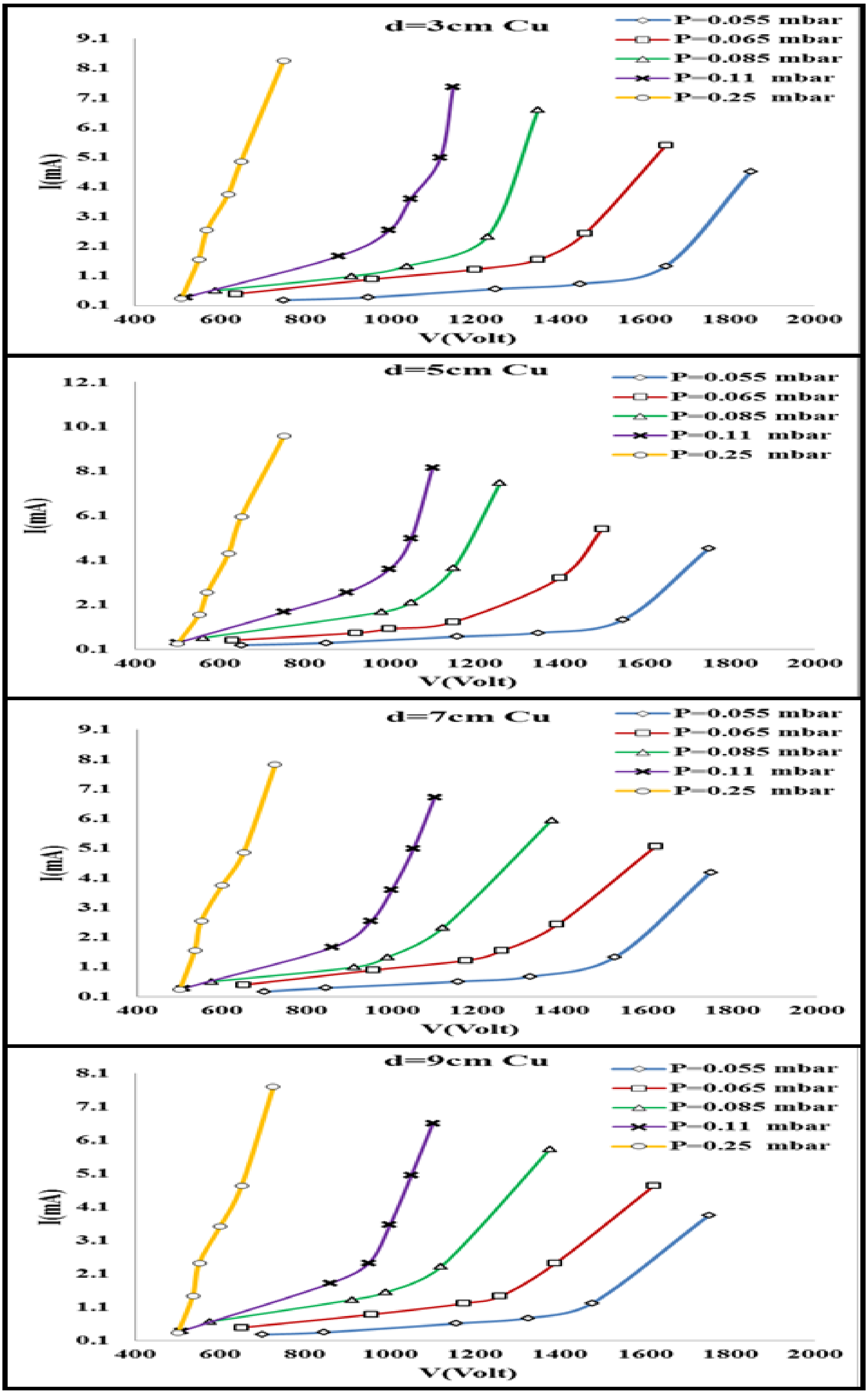


Fig.(3) The variation of discharge current with applied voltage at different working pressures of Ar gas for different inter-electrodes spacing using Cu target.

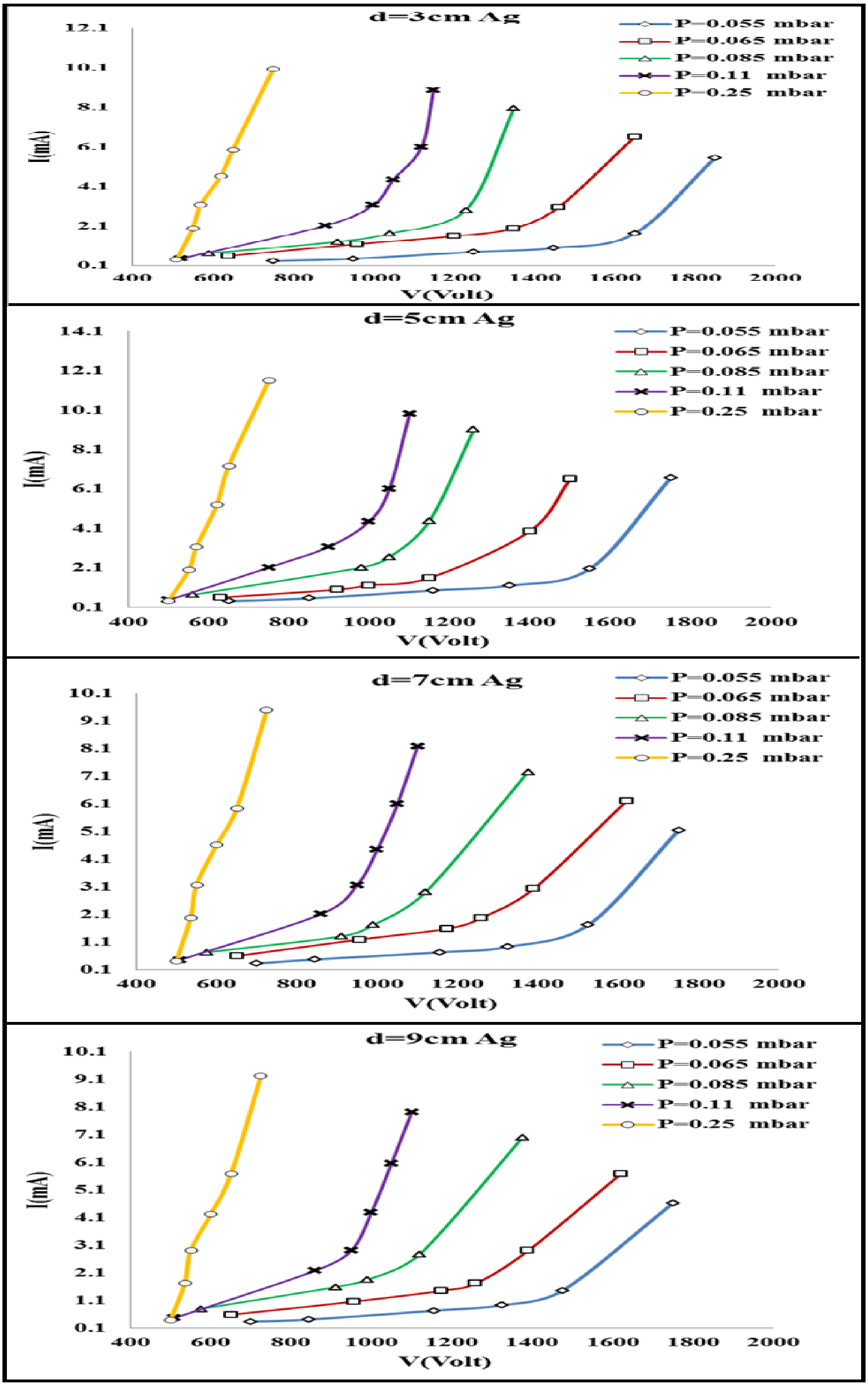
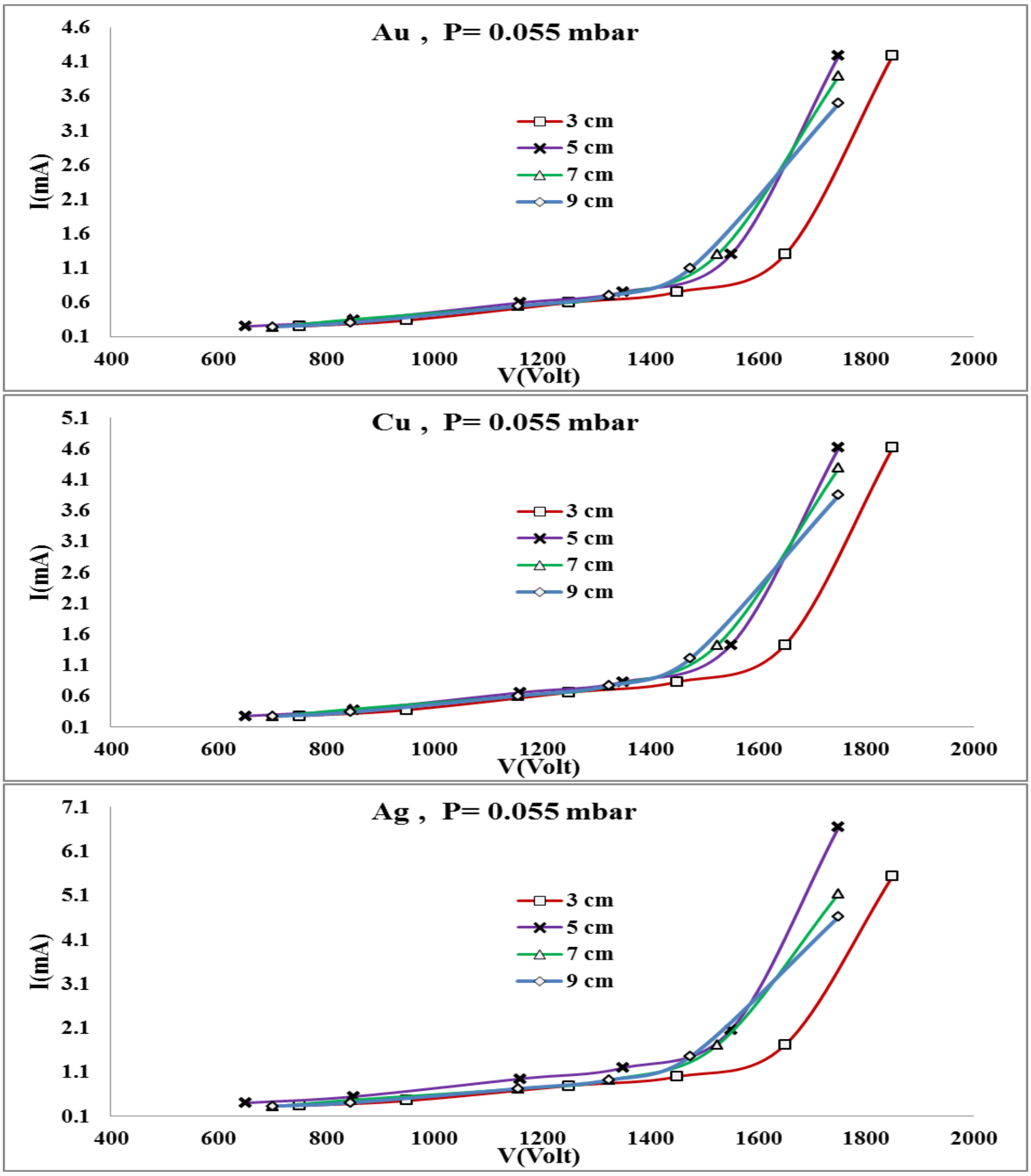


Fig.(4) The variation of discharge current with applied voltage at different working pressures of Ar gas for different inter- electrodes spacing using Ag target.

Figs (5) show a comparison between the current-voltage characteristics of the dc glow discharge for constant pressure (0.055 mbar) with different inter-electrodes spacing (d) for argon gas presented for gold, copper and silver. From this figure, it can be seen that at 5 cm inter-electrode spacing the discharge current become higher compered to other distances for all used targets..



Fig(5): The variation of discharge current with applied voltage at different distances of Ar gas for silver target.

Fig. (6) shows a comparison between the current-voltage characteristics for gold, copper and silver of the dc glow discharge with constant Ar constant pressure (0.055 mbar) and constant inter-electrode spacing (5 cm). From this figure , it can be seen that the discharge current depend on electrode material, where the current decrease with increasing metal work function.

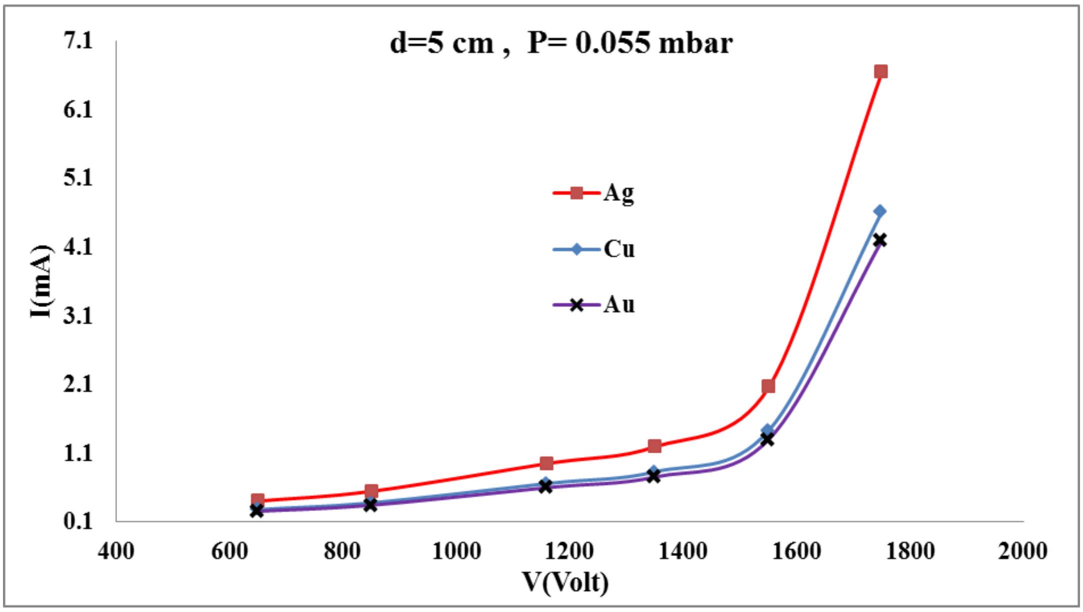


Fig.(6) The variation of discharge current with applied voltage at d=5 cm and P= 0.055 mbar of Ar gas for different target.

The current-pressure characteristics of the dc glow discharge for different electrodes materials at constant inter-electrode spacing (d =5 cm) and constant applied voltage (V=1000 volt) for argon gas presented in Figs (7) using gold, copper and silver targets respectively. The current was varied by changing the working pressure. It can be seen from this figure that the I-P relation is non linear, where the current increase with increasing pressure reaching maximum values then decrease at high pressure show in Fig(7).

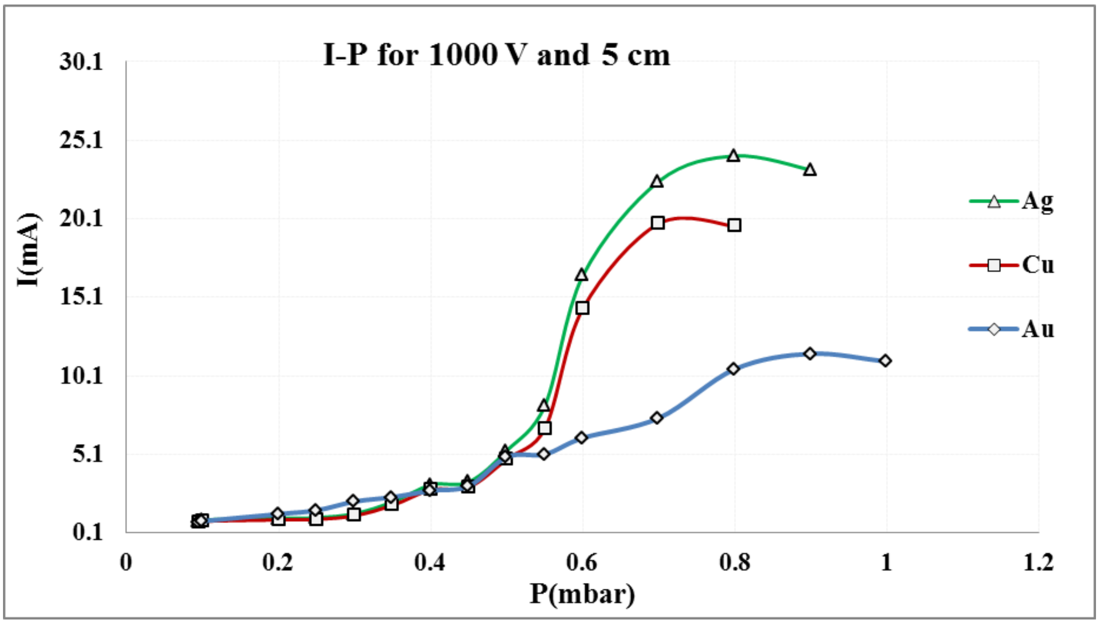


Fig.(7) The variation of discharge current with different working pressures for different target.

Electrical breakdown of gases is the transition from an insulator to a plasma state at what is called breakdown voltage VB [8]. It is well known that, the breakdown curves of the glow discharge are described by Paschen's law VB = f (Pd), i.e. the breakdown voltage depends on the electrode spacing (d) and the gas pressure

(P), The breakdown voltage also depends on factors such as type of gas ,cathode material and magnetic field strength.

Fig. (8) shows the breakdown curves for argon measured with different inter-electrode spacing with different targets (Au, Cu and Ag). At low pd values before the Paschen's minimum the average length of 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. Excitation competes against ionization and higher voltage is needed to produce more ions. Moreover at higher pressures, the ionic mean free path is lower and ions lose energy in the gas by elastic and resonant charge exchange collisions. Higher voltage is required to maintain sufficient ion energies[9].

It follows from this figure that on increasing the gap (d) the breakdown voltages has a few increments, but the pd values being near constant due to losses of charged particles on the lateral walls of the discharge tube due to the diffusion across the electric field[10].

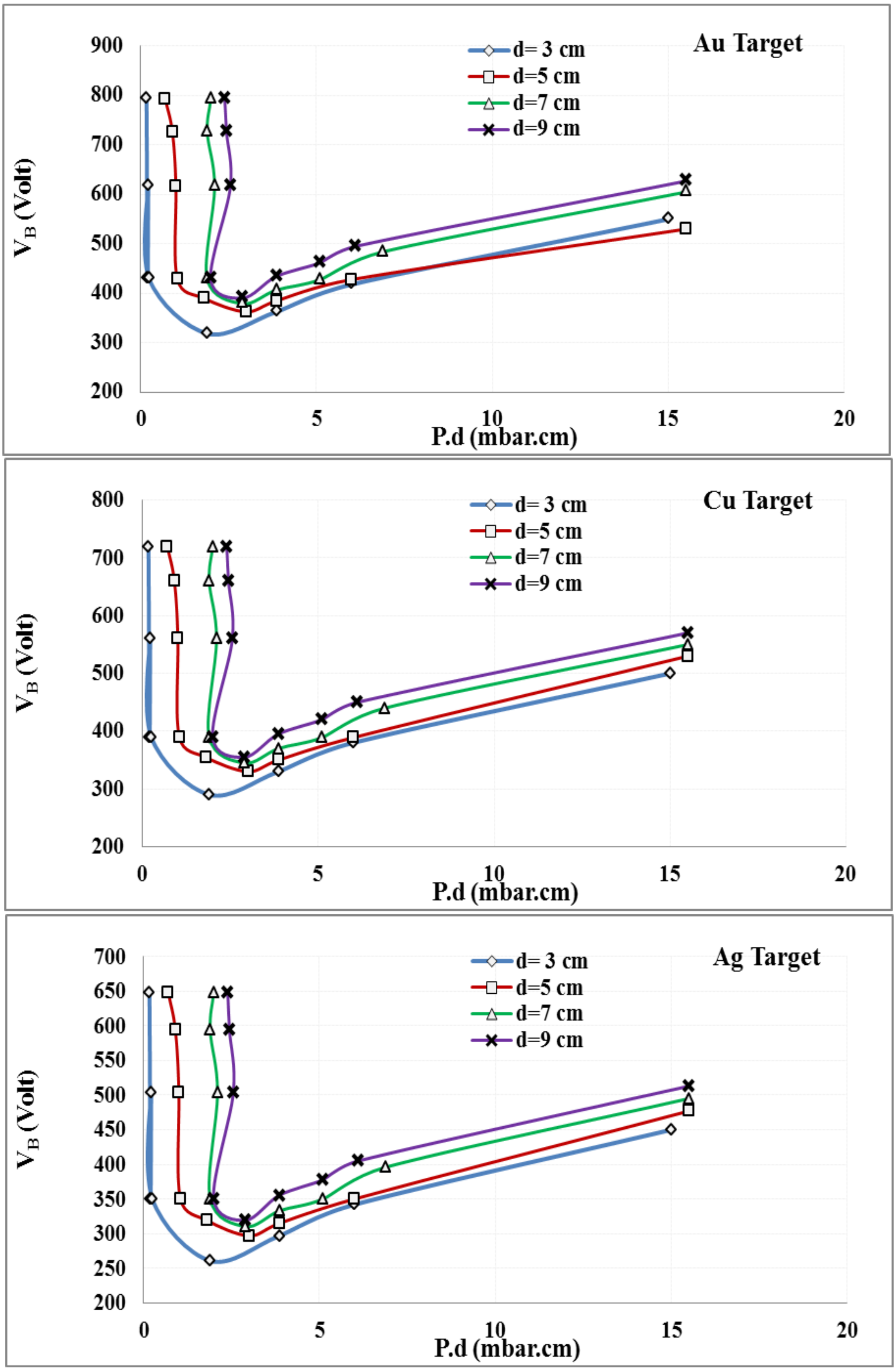


Fig.(8): Paschen curves of the glow discharge in argon for the Ag cathodes for different inter-electrode gaps.

Fig. (9) shows a comparison between Paschen curves at constant distance for different targets. This figure indicates that the Breakdown voltage varies with varying target where the Au curve is higher one while the Ag curve is lower one.

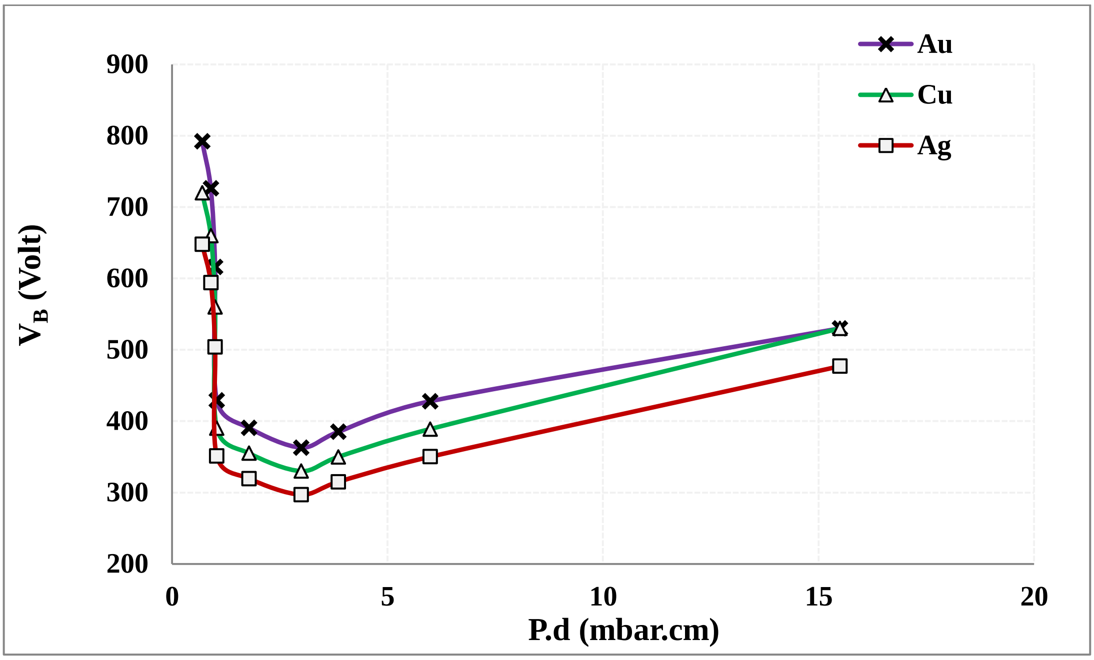


Fig.(9) Paschen curves of the glow discharge in argon for the Au, Cu and Ag cathodes and d=5 cm.

Table (1) : Breakdown voltage and pd min for argon gas using different targets and different inter electrode distance.

	Enter electrode distance	d=3 cm	d= 5 cm	d=7 cm	d=9 cm
Au	Breakdown voltage ($V_{B\ min}$)	319	363	379.5	390.5
	Pd $_{min}$ (mbar.cm)	1.89	3.02	2.85	2.84
Cu	Breakdown voltage ($V_{B\ min}$)	295	330	345	355
	Pd $_{min}$ (mbar.cm)	1.89	3.11	2.80	2.86
Ag	Breakdown voltage ($V_{B\ min}$)	290	297	310.5	319.5
	Pd $_{min}$ (mbar.cm)	1.89	3.03	2.86	2.79

4. Conclusions

This home-built dc- sputtering system has long stable operation using argon gas.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 metals sputtering application.

5. References

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