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Study of sputtering parameter in D.C. planar magnetron sputtering

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Abstract:
In this research used the D.C. planar magnetron sputtering and measurement the some parameter to magnetron sputtering to effect to deposition thin film; this parameters were the pressure, voltage the glow discharge, distance between the target and the substrate, and thickness for thin film. We found the best conditions in the pressure (300mtorr) and distance (4cm) to good thin film.

الخلاصة :
في هذا البحث استخدم الترذيذ المغناطيسي المستوي والمستمر وحساب بعض عوامل الترذيذ المغناطيسي المؤثرة على ترسيب الاغشية الرقيقة. وهذة العوامل هي ضغط الغاز، وفرق الجهد التوهج، والمسافة بين الهدف والارضية وسمك الغشاء الرقيق؛ ووجدنا ان الفضل الشروط كانت عند ضغط (300mtorr) ومسافة (4cm) لافضل غشاء رقيق.

1- Introduction

Magnetron sputtering is a technique which is successfully applied in deposition of a variety of thin films. Its high deposition rate and good control of sputtering parameters make this technique very powerful for various metallization applications. One of the requirements for sputtering is the presence of an inert gas which, after ionization becomes a sputtering medium. Typically 10-2 to 10-3 Torr pressure of inert gas, e.g. argon, is required to perform sputtering. It has been shown, that the incorporation of argon in various metal films leads to stress formation [1-3], and increase of receptivity [4]. Various attempts have been made to lower the pressure of working gas at which magnetron sputtering can still be performed or eliminate this gas completely. The pressure reduction in magnetron sputtering was usually achieved by increasing the gas ionization, for example by shaping or increasing the magnetic field in the near target region [5-7] There are several types of magnetron for practical applications. The most common configurations are:planar in this type of magnetron electrode configuration the target surface are planar, and the B-field is created by permanent magnets behind the targets. This kind of configuration is widely used in tours magnetron sputtering sources. During deposition the substrate are stationary in front of the target. A "looping" magnetic field is used, and this restricts the sputter erosion of the target to a "racetrack" area [8].Cylindrical This type of magnetron systems has a cylindrical geometry and axial magnetic field. With the inner cylinder as the target, the arrangement is a cylindrical magnetron or post magnetron. This configuration has the ability to coat a large area of small substrates. [9] RF sputtering One of the limitations of simple D.C. diode systems is that they cannot sputter insulators. This is due to the fact that glow discharges cannot be maintained with a dc voltage if the electrodes are covered with insulating layers. Hence the technique of R.f. sputtering was developed wherein an ac voltage is applied to the electrodes [8]. AC glow discharges are operated at 13.5 MHz frequency. A magnetic field can also be used with R.f. sputtering to increase the rate of deposition. The introduction of R.f. sputtering greatly extended the range of the sputter deposition technique and hence sputtering can be used for a wide range of materials [10]. The planar magnetron has emerged as an elegant embodiment of the long-sought [11-13] high rate sputtering source. In the classic dc or R.f. sputtering arrangement consisting of a planar cathode and its surrounding dark-space shield with the essential addition of permanent magnets directly behind the cathode, the magnets are arrayed so that there is at least one region in front of the cathode surface is a closed bath.The basic principle of all magnetically enhanced sputtering techniques was discovered by Penning[14] and further developed by Kay and others [15-21] , Penning`s work had led earlier to the invention of the getter-ion pump [23], the development of which also indirectly contributed to the understanding [21-24] and enhanced of magnetically enhanced sputtering sources [25].The first practical magnetron sputtering cathode was developed by Chapin [20]. He showed that the magnetic field lines (Used permanent magnets) should have a line of entry and a line of exit so that the area between these two forms a race track erosion zone. Nyaiesh and Elphich [18] designed a planar magnetron using electro magnetic coils.Rastogi et. al. [19] used U shaped demountable magnetic field lines run parallel to the target.The planar magnetron structure is in example of an embarrassingly "obvious" solution to a technological problem that eluded discovery and implementation for more than 50 years. One of the first descriptions of a planar magnetron device may have been that of Kesaev and Pashkova [4, 14] who, in mercury arc lamp studies. The plasma region is in the shape of an elongated ring which, in the case of along cathode, behaves as two parallel line sources. The two configurations are shown in figure (1). [4]Magnet arrangement can be varied substantially, the only constraints being those of geometry and the requirement that there be at least one closed path where the magnetic field lines are parallel to the cathode surface. The maximum transverse component of magnetic field in front of the target is typically in the range 200-500 G (0.02-0.05 T).[4] The cathode assembly consists of the source material, generally 3-10 mm thick. Cooling in planar magnetron sputtering is critical because of high power dissipation at the cathode. The planar magnetron sources usually are operated in argon at a pressure of 1-10 mTorr and at cathode potentials of 300-700 V. Under these conditions, current densities can vary from 4 to 60 mA/cm2; power densities are in the range 1-36 W/cm2.

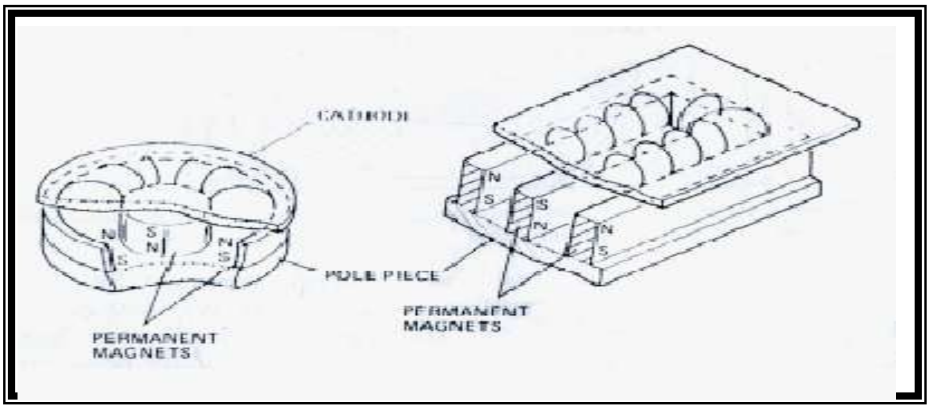


Figure (1)Circular and rectangular planar magnetron sputtering soures [4].

Typical voltage-current characteristics are shown in figure (2) for various pressures. Thus, for a given cathode material and configuration the magnetron operates at some characteristic, nearly constant voltage.

Figure (3) displays the same data as figure (2) in terms of the voltage required to maintain a constant average current density at various pressures. [4]

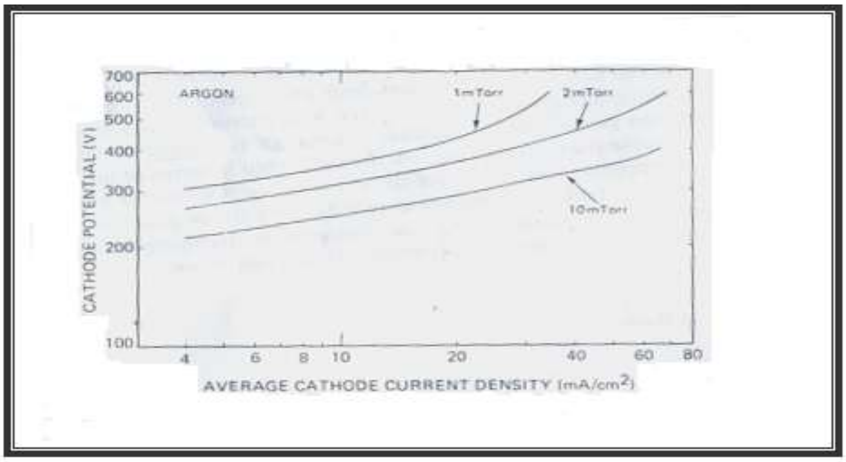


Figure (2) Ccurrent-Voltage characteristics [4].

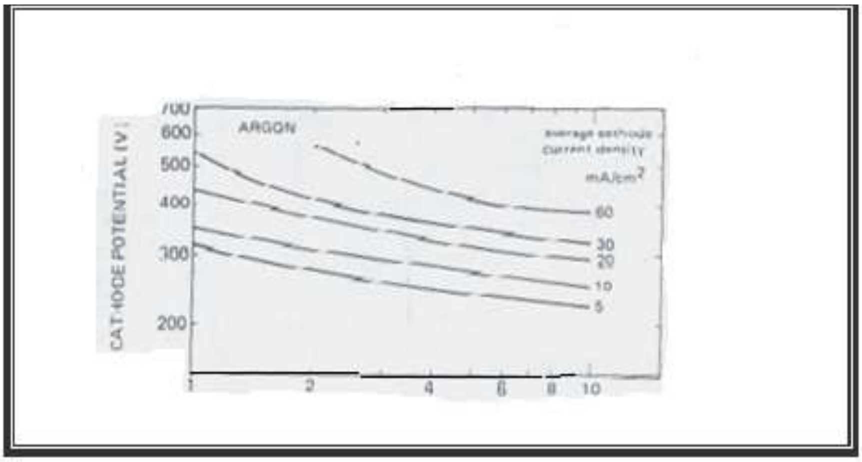


Figure (٣) Cathode Voltage-Pressure characteristics[4]

2-The experimental

The experimental method of magnetron sputtering that followed to preparing thin film explained the steps which have been followed to design and produce a vacuum chamber and sputtering target that is very important to have a suitable environment to prepare thin film. In addition to that parameters which influence the sputtering process had been studied.We design this system as the same as the Edward's system and made by the Heavy Engineering Equipments state Company (H.E.E.S.Co.). Figure (4) show picture for the system. The system has the several parts, which is: The Target We designed and constricted a target from copper and it contains of two parts; the first part as a flange used as a cover with thickness of 1 cm and 13 cm diameter. The second part has the same diameter in the first part but it contains cooling pond with 4 cm height and 6.5 cm diameter. A groove with diameter 7.5 cm, depth of 0.1 cm and width of 0.15 cm which has used for O-ring. The cooling pond contains a magnet with circular shape has 6 cm as outer diameter, 4 cm as inter diameter and 3 cm height used for producing magnetic filed. The cooling pond has 2 pipes one for inlet and the second for outlet water. Figure (5) shows this design.

Figure (4) show picture for the system

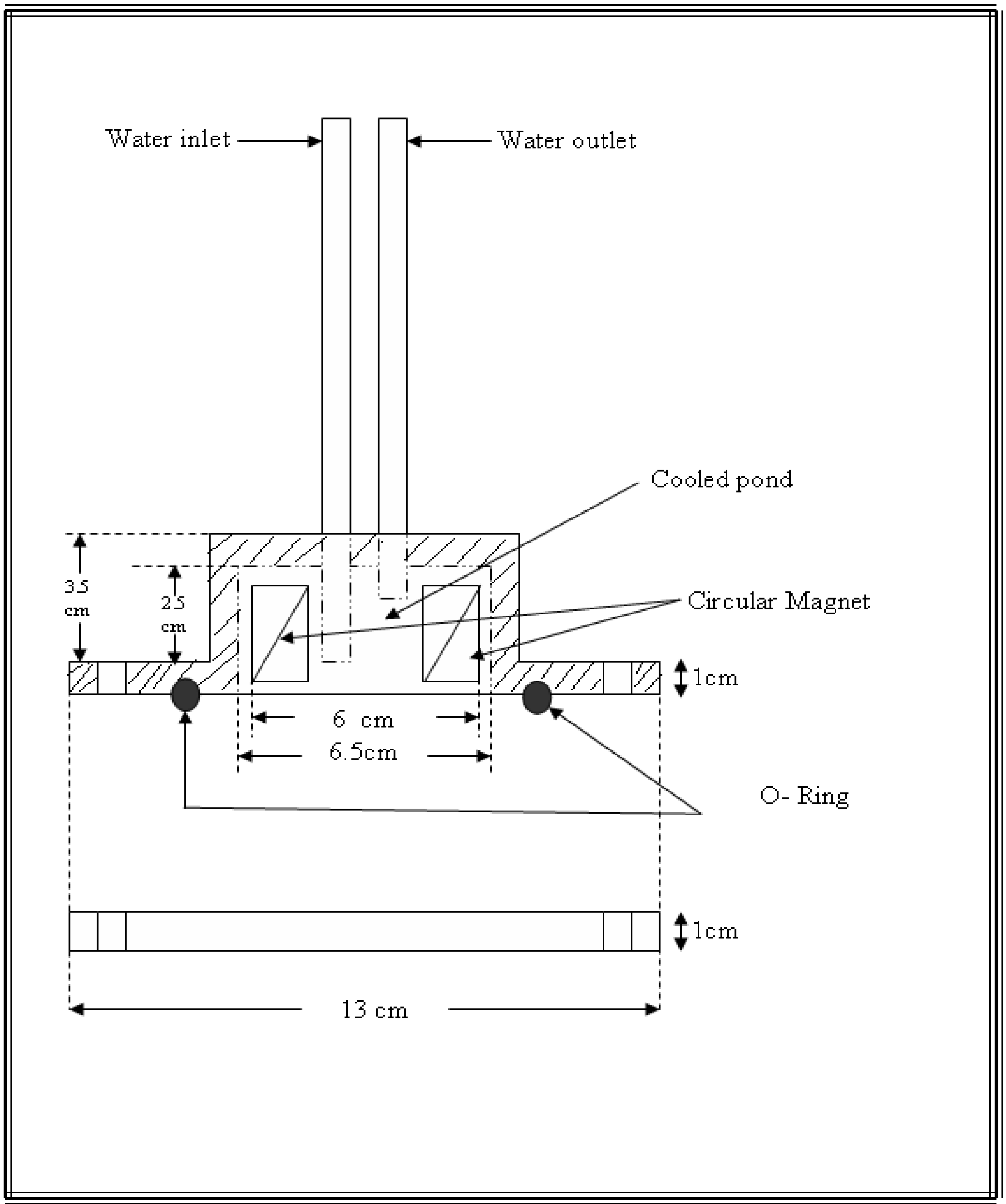
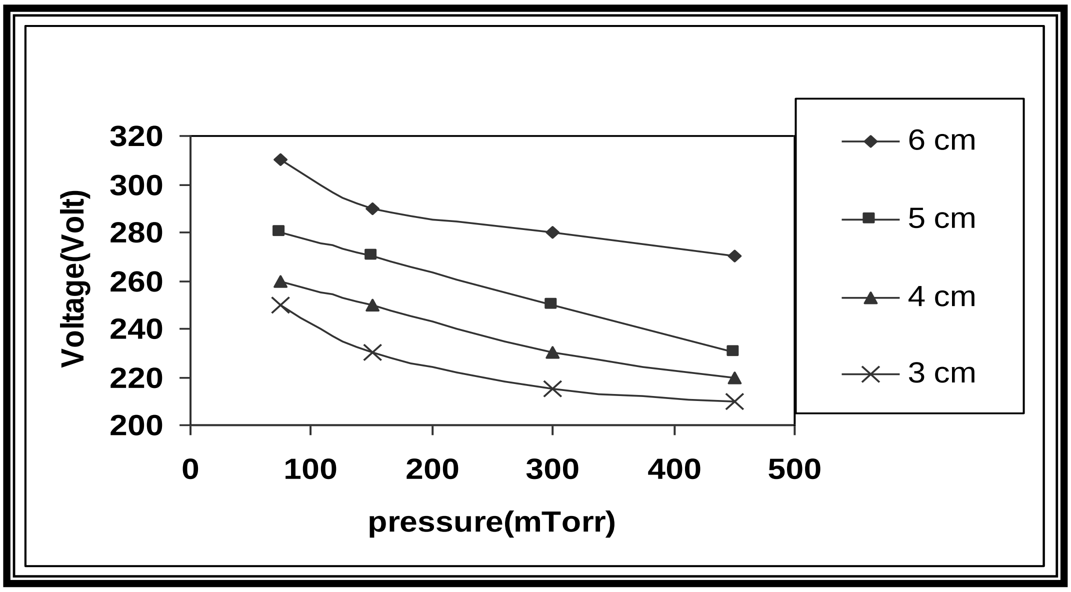


Figure (5) the target diagram

4- Results Discussion

There are several parameters that influence magnetron sputtering process such as distance, pressure and thickness. Figure (6) shows this variation of target voltage as a function of argon pressure for different distances. One can observe from the figure below that the target voltage decreases progressively with increasing argon pressure.



Figure(6) The variation of target voltage as a function of pressure of different distance**.**

Which can be attributed to that the target voltage decreases when argon pressure increase. For different distance (d= 5, 4, 3 cm). Pressure for a given amount of applied power, higher sputtering rates will usually be obtained under conditions which favor high current and low voltage. This is because the number of ions striking the target is directly proportional to the current whereas the sputtering yield tends to increase at a less than linear rate with increasing applied voltage. With increasing pressure the current in the discharge increases while the voltage decreases so it is not surprising the deposition rate will usually increase with pressure. The atoms density will be increased with increasing argon pressure that leads to increase the number of ionic collisions that's to emit a secondary electron which assists to increase the process. All the reasons that we mentioned led to reducing target voltage for each distance and it had been noticed that when we directed toward decreasing the distance the target voltage was decreased for all pressure which had been used. This behavior may attribute to decreasing the free path of electron as a result to decreasing the distance.The erosion track which depends on the distribution of the magnetic field on the target is a ring with an internal diameter of 9 cm and an external diameter of 11 cm. maximum erosion is seen in a track of about 3 cm width with a mean diameter of 11.5 cm.Figure (7) shows the thickness of film as a function of pressure one can observe from this figure that the film thickness increases with increasing the argon pressure until it reach as the maximum value of thickness at 300 mTorr then decreased. This may be attributed to increasing the number of collision by increasing the pressure.If we try to discuses the decreasing which was occurred in film thickness after pressure 300 mTorr as we mentioned before, Where the number collision increases by increasing the pressure that led to secondary electrons increase and secondary electrons collision with target that led to the sputtering rate increase consequently which led to thickness increase. That happens before pressure 300 mTorr.

At pressure 300 mTorr according to Pastern's law. The atoms sputtered atoms will be collision with each other. So, the atoms will not be going to the substrate.

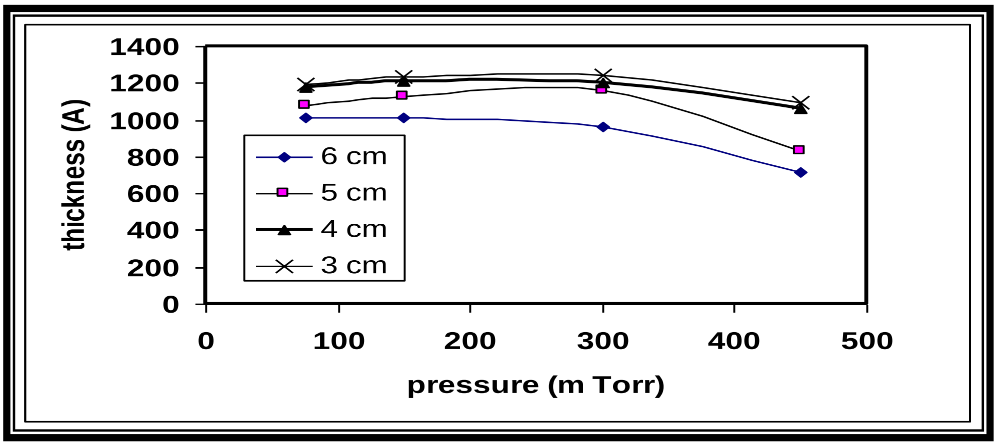


Figure (7) The variation of film thickness of a function of pressure

As the pressure increases, an increasing fraction of the material that leaves the target does not reach the substrate but returns to the former through back diffusion. For maximum deposition rate, pressures in the order of about 300 mTorr would appear.The same thing for other distances it must be said, the film thickness increased by decreasing the distances from 6 cm to 4cm, when distance reduce, the gap between the target and substrate by that the sputtering atoms need to low value of energy reach the substrate. While for other distance 4 cm and 3 cm it had been noticed that the variation of thickness was not large that may attribute to convergent the distance with the free path of sputtering atoms.Most of the above observations lead us to believe that any understanding of the sputtering process would require the analysis of plasma in such processes. This would not only help in improving the control over process parameters but also further improve the technique to obtain quality films.

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