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Design and Fabrication of a DC Cylindrical Magnetron Sputtering Device

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Abstract

A dc cylindrical magnetron sputtering device is designed and its characteristics are studied. The device consists of two copper cylinders with 1.5 and 5 cm in radius and 20 cm in length. A magnetic coil mounted around the outer cylinder generates an axial magnetic field up to 550 G. The effect of different magnetic field on the ionization rate of the discharge is observed. It is shown that the electrical behaviour of the discharge strongly depends on the values of the magnetic field and shows an optimum value at which the power absorbed by the plasma is maximum. The effect of different pressure on the ionization rate is also studied and the results are reported.

Keywords:

magnetron, glow discharge, sputtering, thin film, conductance of thin film

1. Introduction

Deposition of thin films may be achieved by the following methods.

Reactive thermal evaporation deposition, RF & DC magnetron sputtering, electron beam evaporation, ion-assisted deposition techniques, electroless chemical growth techniques, spray pyrolysis, chemical vapor deposition, vacuum evaporation and laser-assisted deposition techniques [1].

Sputtering techniques are commonly used to deposit metal thin film on insulating and conducting substrates. The growth parameters, such as thickness of thin film and sputtering power usually play significant roles in governing the properties of metal films [2].

Plasma sources are nowadays widely used for sputtering and film deposition application [2, 3]. A dc magnetron sputtering device plasma is essentially a glow discharge produced between two cylindrical electrodes as anode and cathode. A magnetic coil located outside the cylinders creates a field configuration acting as a magnetic trap for the electrons [4], which typically have a temperature of a few eV. A strong ionization source is thus produced in the region located at the front of the cathode. The ions created in this region are accelerated towards the cathode, causing sputtering from its surface. In this paper variations of voltage and current of a dc magnetron sputtering device for various pressures and magnetic fields are studied and optimum values for these parameters are obtained.

2. Experimental set up

In Fig. 1 the schematic view of the system is pre-

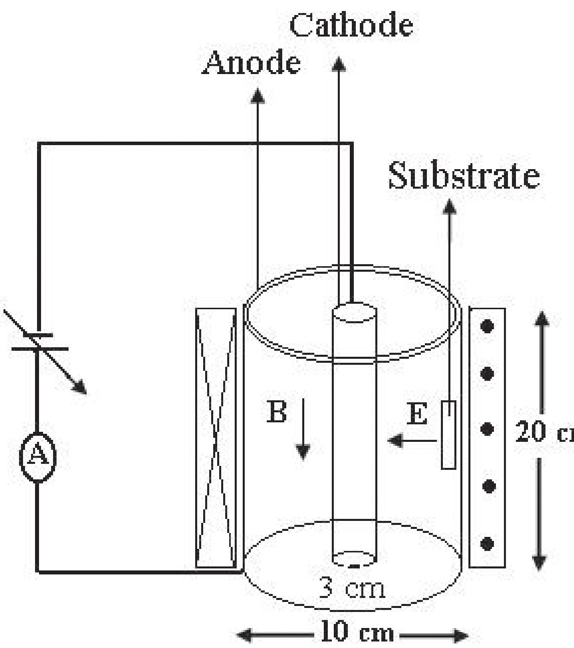

Fig. 1 Schematic of the customized system (coaxial DC magnetron sputtering device).

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sented. As shown it consists of two coaxial cylinders used as cathode (inner one) and anode (outer one). Diameters of the cylinders are 10 and 3 cm with 20 cm length. The gas used in this apparatus was Argon at the pressure of 10^{-2} Torr. The system was evacuated by means of a mechanical and also a turbo-molecular pump. A high voltage power supply up to 2 kV was used to maintain the desirable voltage across the electrodes. A nearly uniform magnetic field, parallel to the axis of the cylinders, was generated by a coil (900 turns) around the outer cylinder. The samples used for deposition testing were 4×2 cm pieces of plane glass chosen as substrate which could be mounted on the anode as shown in Fig. 1.

3. Results and discussion

The voltage between cathode and anode versus the discharge current has been measured for various magnetic field under a constant pressure of $P = 0.02$ Torr.

These variations which are shown in Fig. 2 clearly indicate that the relation between the current and voltage tends to be nonlinear for a critical value of magnetic field, i.e. 190 G, under the above mentioned conditions. In Fig. 3 the power absorbed by the plasma is plotted under constant voltage (600 V) and pressure (0.02 Torr) and for different values of magnetic field. As shown the curve shows a peak at 190 G of magnetic field. For testing this result, a few samples were deposited by the apparatus under equal condition but different values of magnetic field, and their thicknesses were measured and compared. For this purpose Cu was chosen as depositing material and some pieces of 2×4 cm glass plate as the substrates. The thicknesses of the thin films under constant deposition time ($t = 5$ min) were measured by testing their resistance of which the results are shown in Fig. 4.

For measuring the thickness of the samples we have supposed it is lineary related to its resistance, though we know different parameters should be taken into account such as degree of film continuity, method of film preparation, electrode effect, chemical reactivity, etc. However as we have been interested only in comparing them, we have ignored and filtered out these parameters.

As shown the maximum thickness was obtained for the sample produced under 190 G magnetic field corresponding to the peak power shown in Fig. 3. To in-

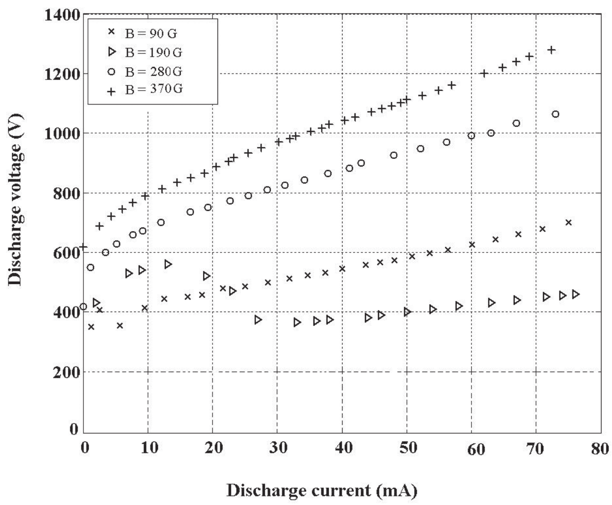

Fig. 2 Variation of voltage versus discharge current at $p = 0.02$ Torr and different magnetic fields.

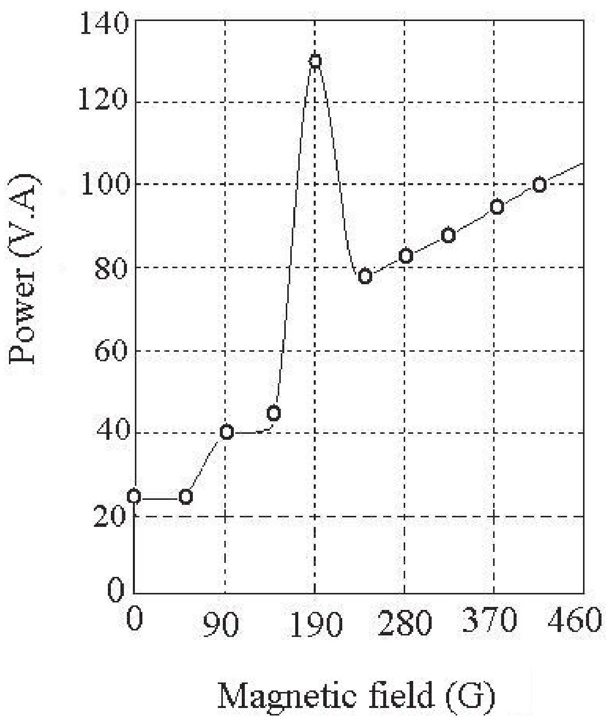

Fig. 3 Variation of power absorbed as a function of magnetic field under constant voltage (600 V) and pressure (0.02 Torr).

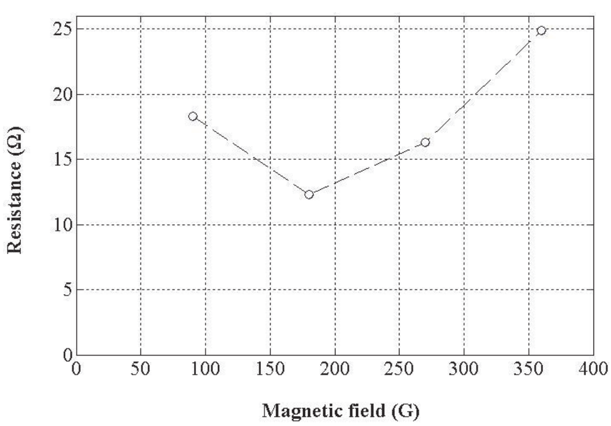

Fig. 4 Variation of resistance of the thin films as a function of magnetic field under constant deposition time ($t = 5$ min) and pressure ($P = 0.02$ Torr).

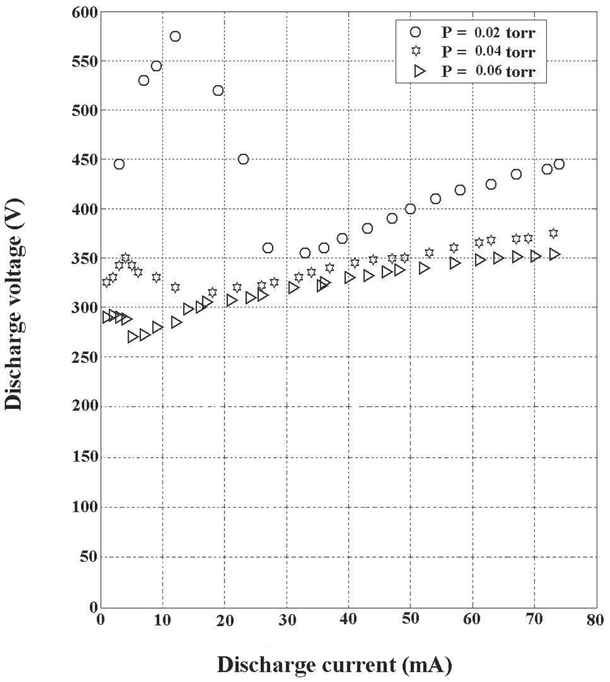

Fig. 5 Variation of voltage versus discharge current at $B = 190$ G and different pressure.

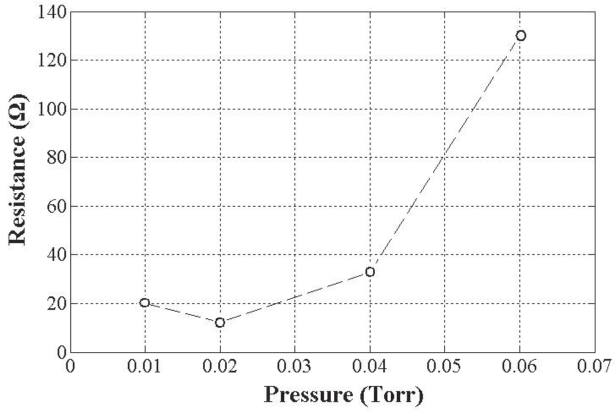

Fig. 6 Variation of resistance of the thin films as a function of pressure under constant parameters: deposition time ($t = 5$ min), discharge current ($I = 70$ mA) and magnetic field strength ($B = 190$ G).

terpret the result we note that when the magnetic field is increased more than its optimum value, the electrons trapped in the magnetic field cannot reach the cathode and thus the current tends to decrease. On the contrary when the field diminishes, it reduces the degree of ionization and thus again the discharge current decreases.

In a similar way, the effect of different pressures on V-I curves under constant magnetic field $B = 190$ G are shown in Fig. 5. The effect of different pressures on the thickness of the thin films under constant deposition time ($t = 5$ min) is also shown in Fig. 6. As shown the pressure shows an optimum value (in this case 0.02 Torr) when the magnetic field strength ($B = 190$ G) and the discharge current ($I = 70$ mA) have been kept constant.

4. Conclusion

The characteristics of a cylindrical dc magnetron sputtering device have been studied. We have shown that at an optimum value of the magnetic field there is a maximum value for the power absorbed by the plasma. At this optimum value the activity of the system is maximum which has been shown by testing the thickness of the deposited film on a substrate. The pressure has also shown a similar effect on the deposition rate of this magnetron sputtering device.

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