A COMPLEX-TYPE FOCUSSED MAGNETRON FOR SPUTTERING*

Zheng Sixiao(郑思孝)

(*Institute of Nuclear Science and Technology, Sichuan University, Chengdu 610064. China*)

ABSTRACT

The design of a small complex-type focussed magnetron with a long target-life used for excited multi-atoms beam film deposition in hard coatings is described. The magnetron tunnel of the magnetron source was constructed by a planar unbalanced magnetic annulus, which comes from the extended co-axial magnetron principle and inside cylindrical magnet tunnel. The use efficiency of inside circular cone sputtering target area is high up to 62%. The inside-inversion cone sputtering target has a long life and results in a higher deposition rate 35 nm/min for Ti at a 2.5 Pa Ar pressure. A better focussing direction of ejecting atom beam has been achieved, and the arc power input is 300W for Ti target.

Keywords Magnetron sputtering source, Focussed atomic beam, Target life, Ti and pure graphite targets

1 INTRODUCTION

In recent years magnetron sputtering has been developed from balanced magnetron sputtering to unbalanced magnetron sputtering. Four different magnet systems have been used for the study of basic physics on thin film growing and for the uses of metallurgical coatings, miscellaneous other coatings, and in ion mixing of refractory metals[1].

In order to increase the use efficiency of sputtering target area with a long sputtering target-life and better direction of the ejected atoms compared with a small circular planar unbalanced magnetron sputtering source[2], a new small complex-type magnetron has been developed and studied.

2 CONSTRUCTION OF FOCUSSED MAGNETRON SPUTTERING SOURCE

The co-axial magnetron principle is extended in the planar annulus magnetic tunnel part of this source. The permanent magnets embedded in a mild steel annulus of 26mm inside diameter are combined as a planar annulus magnetic tunnel by 8 segments of magnets, the S pole-face of the magnets facing the centre of circular planar annulus[3], see Fig.1.

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The loop magnetic field tunnel on the circular cone target surface is provided by the S pole-face of the magnetized mild steel embedded in the centre of the magnets and the N pole-face of the cylindrical annulus permanent magnets. The tunnel magnetic strength on the surface of the target is from 30 mT to 50 mT (3 mm away from the inversion cone target surface).

The cylindrical body of the focussing magnetron source was made of aluminium with a 64 mm diameter. The sputtering target was combined with a planar circular of 35mm diameter, 3 mm thickness, a cylinder of 35 mm outside diameter, 2.5mm thick 3 mm length, and an inversion cone with an inclined angle of 45° and 10 mm in length. Sputtering target was pressed closely into the inside-surface of the magnetron cave formed by the water-cooled aluminium body for good cooling. The aluminium cylinder also decreases the remanant magnetic field strength to below 12.5 mT on the unwanted glow discharge region in order to avoid the unnecessary contamination.

Two copper pipes were used as the cooling returning, and also used as a lead-in electrode connected with the cathode target body. The magnetron sputtering source was mounted in two insulated lead-through electrodes by two water-cooled copper pipes.

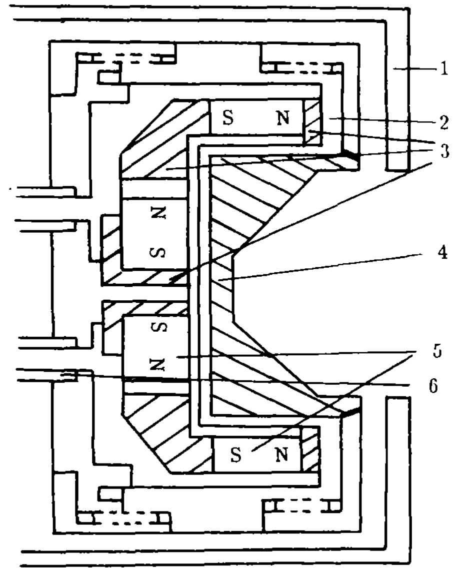

Fig.1 Construction of the focussed complex-type magnetron sputtering source

1 Anode 2 Aluminium body 3 Mild steel 4 Ti target 5 Permanent magnet 6 Copper water return pipe

The motion radius of the electron in a spiral way $r = ME/eB^2$, electric field strength $E = -V/D$, V is the cathode potential. The distance D between the cathode and anode was selected to be small than $D = 2r$, then $D = 2(M/2e)^{1/2} \times (-V)^{1/2}/B$, it could eliminate the unnecessary glow discharge. For a cathode potential V=-800V (applied the initial arc potential of discharge for graphite target), $B = 12.5\,\mathrm{mT}$ we can get $D = 6.9\,\mathrm{mm}$. The 6 mm distance between cathode and anode was selected.

3 EXPERIMENTAL RESULTS

The small focussed magnetron beam was running in a large discharge current condition from 200 mA to 700 mA, the applied anode potential was from 215V to 240V, at a Ar pressure of 2.5 Pa for a Ti target. The discharge began at an anode potential was 550V then the arc potential dropped down to 215V with a discharge current of 200 mA. The discharge current increased from 200mA to 700mA with the increment of the arc power input from 215V up to 240V. and the arc power input increasing from 43W (200 mA at 215V) to 168W (700 mA at 240V). the total power input increased from 58.5W (1.3A at 45V) to 295.5W (4.2A at 68V). the arc power input was only 300W.

A Ti deposition film on a sheet of glass at 250V/500mA discharge condition formed a mirror in ten minutes. The deposition rate of Ti was 35 nm/min at a 2.5Pa Ar pressure. The area of the film was 28 mm diameter. which showed a better focussing direction of ejecting atom beams and supplied a long life of target for this thick inversion cone target. The deposited rate was higher than the deposition rate of the small unbalanced magnetron sputtering source[2].

For pure graphite target at a 2.6 Pa Ar pressure discharge began at the anode potential of 800V. then the arc potential dropped down to 550V with are current of 200 mA. While the applied anode potential was raised from 550V to 640V. the discharge current was increased from 200 mA up to 700 mA with the arc power input increased from 110W (200 mA at 550V) up to 448W (700 mA at 640V). meanwhile the total power input was increased from 180W (1.5A at 120V) up to 652.5W(4.5A at 145V). Because the heat conductance for graphite was not very good. it can not be running over 300 mA discharge condition. otherwise all the graphite target body would be heated to red in several minutes. At a lower arc condition of 150 mA at 400V. the deposition rate of pure graphite target was 12 nm/min. The sputtered graphite atoms transformed directly to a hard golden yellow insulated carbon film on a Si sheet substrate.

The use efficiency of the inside circular cone target area was high up to 62%.

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