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Research on the environmental protection of magnetron sputtering coating for multi-contour cavity structure products

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Although chemical coating is mature, with the increasingly serious environmental pollution, limited or prohibited production is inevitable. The common coating method could not be used for the contour cavity structure product as the structure of the product is too complex. Normally, the problem includes: (1) low target utilization rate, (2) not uniform film thickness, and (3) no dead cavity coating. In this paper, some strategies were used to solve the above problems: (1) Multiple rotating cylindrical magnetron sputtering targets were installed to improve the efficiency and uniformity of films; (2) Multiple magnetron sputtering targets and an auxiliary magnetic field were set to improve the plasma density of the vacuum coating chamber and the uniformity of the film on the inner cavity wall; (3) Appropriate magnetron sputtering process parameters were selected to improve the adhesion strength between the film and the substrate interface. Based on the above strategies, a uniform, compact and continuous composite film can be coated on the multi-contour cavity structure product. Magnetron sputtering is a physical vapor deposition method which not only meets the technical requirements of complex surface coating, but also abandons the pollution caused by chemical plating problems. It is an excellent green environmental protection process.

Key words: Multi-contour cavity products; Magnetron sputtering; Green environmental protection process; Film uniformity; Homogenization control.

INTRODUCTION

The common coating method cannot be used for the contour cavity structure product as the structure of the product is too complicated. Normally, the problem is that the film thickness is not uniform and not firm, and in the production process it will cause environmental pollution. In recent years, magnetron sputtering coating has been introduced as a novel coating technology. It is a physical vapor deposition technology which does not produce environmental pollution problems. By applying magnetic field on the surface of the cathode target to form an electron trap, the glow discharge on the target surface forms a plasma region and the atom sputtering target surface coats on the substrate surface [1-3]. Compared with the film produced by the common coating process, the film prepared by magnetron sputtering coating is harder, and the process is highly efficient. Recently, magnetron sputtering coating technology has been widely used in many fields, such as aerospace, engineering, electronic components, precision instruments and so on [4-8]. Current magnetron sputtering coating technology is mainly used for products of simple structure. The use of magnetron coating technology for a contour cavity structure product mainly has the following problems [9]:

1) As magnetron sputtering is planar sputtering, for the complex cavity of the product, the cathode magnetic field component will cause uneven local sputtering and will lead to target consumption, uneven surface, concave erosion and will influence the quality of the film;

2) For the complex cavity product, the magnetron sputtering coating displays a selective sputtering phenomenon, and at the same time, an antis puttering effect on the film, which causes a large difference between the compositions of the film and the target; the film is uneven and not strong.

Aiming at the above problems based on the character of the contour cavity structure product, some strategies were developed in this paper to improve the magnetron sputtering coating technology.

METHODOLOGY

Basic principle of magnetron sputtering coating

The basic principle of magnetron sputtering is related to the orthogonal electromagnetic field between the substrate and the cathode sputtering target. By passing into the special gas, the glow discharge on the target surface through the orthogonal electromagnetic field forms a plasma region. Under the action of the orthogonal electromagnetic field, the electrons move along the target surface. At the same time, the motion of the electrons is restricted to a certain space to increase the collision probability between electrons and working gas molecules and to improve the ionization

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efficiency of the electrons. Electrons and argon atoms collide yielding a positive Ar ion and a new electron. After a number of collisions, the electron loses energy to become 'a final electron' entering into the weak electric field. The argon ion is affected by the electric field to bomb the target surface and sputtering target atoms, by the collision between the target atoms, the atom is sputtered onto the substrate surface by kinetic energy transfer. Finally, the atomic target surface sputtering deposition on the substrate surface forms a thin film [10-12]. Its basic principle is shown in Figure 1.

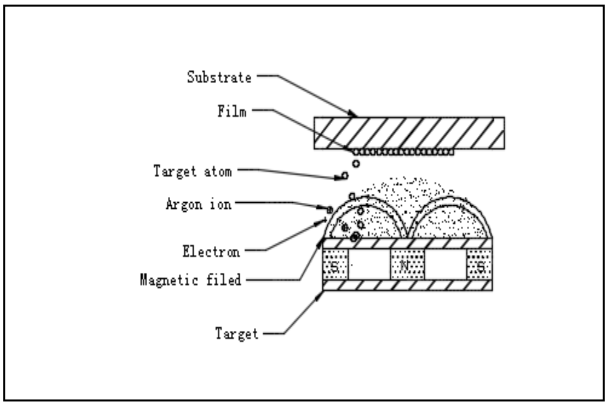

Fig. 1. Basic principle of magnetron sputtering [10]

Internal sputtering coating homogenization control technology for contour cavity structure

Coating the inner cavity of the multicontour cavity structure, the film thickness is uniform and the firm film layer will directly affect the stability and reliability of the coating products.

The key issue of the magnetron sputtering coating technology is how to ensure uniformity and compactness of the film. In this paper, the following strategies are developed to effectively improve and enhance the uniformity and compactness of the films.

1) Use of rotating cylindrical magnetron sputtering target to achieve directional coating

At present, the main target includes a coaxial cylindrical target and a circular planar target, meanwhile, rectangular plane target, rotating cylindrical rectangular target and some special structure targets are also used in the market. The target is mainly composed of a cathode body, a shielding cover, a target and a permanent magnet, a pressing ring, a substrate and other common components. For the multi-edge cavity surface coated multilayer film obtainerd in this study, the rotating cylindrical magnetron sputtering target is used, and multi-targets are installed at different positions of the coating machine, so that the target can be freely rotated to achieve directional coating.

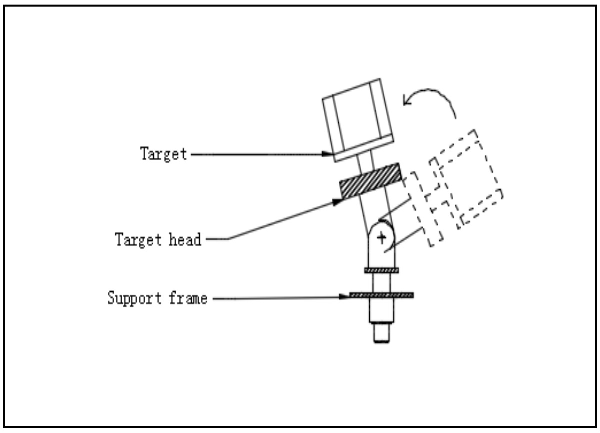

Fig. 2. Rotating cylindrical magnetron sputtering target

2) Set up of a number of magnetron sputtering targets and auxiliary magnetic field to improve the structure of the cathode target

The structure of the unbalanced magnetron sputtering cathode target was improved by using a plurality of magnetron sputtering targets and auxiliary magnetic field, and to improve the density of the vacuum coating plasma chamber, and then to improve the sputtering bias to the deposited coating. At the same time, the reasonable layout of the target permanent magnet ensures the uniformity of the film. Under the requirement of magnetic field strength, the magnetic pole ensures that the distribution of the magnetic field intensity is uniform, thus improving the uniformity of the film and the rate of sputtering. At the same time, the concave target erosion is due to the nonuniformity of the magnetic field component of the planar sputtering cathode target. In this paper, by changing the magnetic field distribution, internal stress of the complex product can be generated in the substrate by sputtering, and a compact continuous and uniform film can be formed.

3) Design of the frame structure of the cathode target rotation and revolution of the cathode target frame structure to improve the uniformity of film thickness

When the substrate and the cathode target are fixed, the uniformity of the film cannot be solved very well. In practice, the contour cavity structure does not move when cathode target rotation and revolution of the cathode target frame takes place. The substrate can be bombarded with the same degree of sputtering particles in different positions. The cathode target frame rotates every week, and a point on the substrate is always in a different position relative to the sputtering target. In this way the film thickness uniformity on the same substrate is guaranteed.

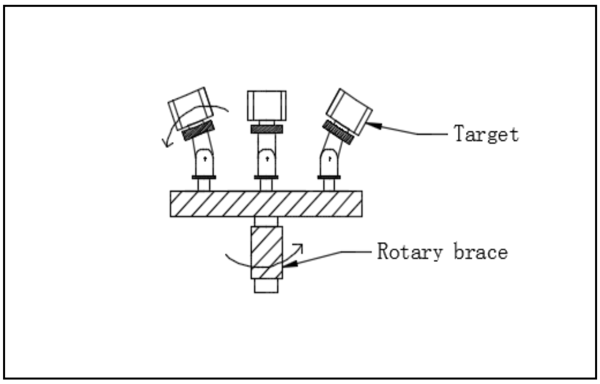

Fig. 3. Cathode rotation and revolution target frame structure

4) Selection of the appropriate parameters of the magnetron sputtering process

The selection of the appropriate magnetron sputtering process parameters, including substrate temperature and gas pressure deposition rate improves the quality of equipment. According to the performance requirements of the film, the sputtering parameters are adjusted to improve the adhesion strength between the film and substrate interface.

EXPERIMENTAL STEPS AND RESULTS

The basic experimental steps are as follows:

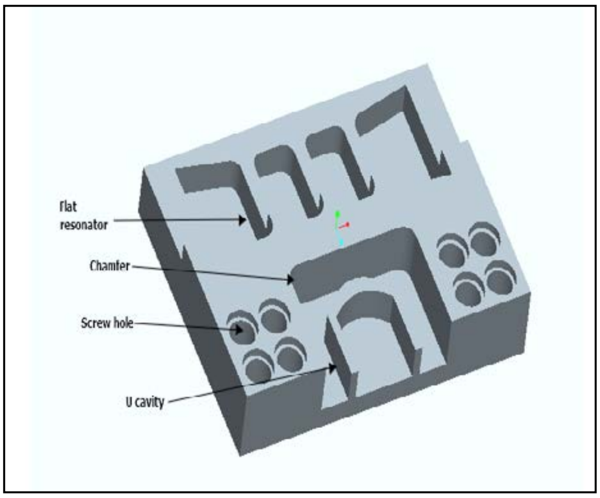

Fig. 4. Structure of the complex cavity

CONCLUSIONS

In this paper, the uniform control method of contour cavity coating was studied. The magnetron sputtering process was improved for contour characteristics of complex cavity structure product through installation of multitargets at different positions in the coating machine, and the target head rotation supports the revolution of the combination model, provides the product surface and complex inner cavity structure with a compact film of uniform thickness. The key technology for complex product cavity magnetron sputtering was optimized.

Table 1. Experimental steps and results

Experimental steps	Contents	Aims
Step 1	According to the requirement of magnetron sputtering cavity structure on the outline of the target, a rotating cylindrical type multi target magnetron sputtering target, sputtering target at different working conditions with a rotating magnetic structure or rotating target structure was used. In the experiment, we used six station magnetron sputtering devices mainly composed of a vacuum detector, vacuum furnace, vacuum system, cathode magnetron, gas input system, and supply, etc.	To improve the utilization rate of the target
Step 2	As the working environment of the contour cavity surface is complex, flexible target head rotation and target head can be used to support effectively sputtering the complex cavity flexible to implement target head rotation and target head can be used to support effectively sputtering the complex cavity .	To realize fixed point
Step 3	Setting the auxiliary magnetic field around the cathode target, by improving the shape and distribution of the magnetic field, as well as setting the shield and other measures, the internal stress of the film coating can be produced by the multi contour cavity wall sputtering. The films were continuous and uniform, and the cathode materials were Ti, TiN and TiAlN.	To achieve compactness and uniformity of the film.
Step 4	In the complicated cavity, a plurality of magnetron sputtering targets and auxiliary magnetic fields are used to form a closed magnetic field in the coating chamber, By interaction of the target with the auxiliary magnetic field, the plasma density increases. Thereby, the contour cavity can reach the purpose of depositing the coating.	To improve the target surface plasma density, and the deposition of the film
Step 5	To the different components of the sputtering phenomenon, and the antisputtering rate of the film, select the appropriate process conditions to minimize the antisputtering effect on the film.	Reducing the reflection effect of the substrate and improving the bonding strength of the film.

Results: thin film without cracks; film thickness between 2 μm~8μm; uniformity is better than 6%; hardness up to 2500 HV; with high strength, no peeling; corrosion resistance, heat resistance and abrasion resistance; high utilization rate of the target; controlled deposition rate (2.0~2000) nm/s; film speed (2~13) μm/h.

Magnetron sputtering is a physical vapor deposition method, which not only meets the technical requirements of complex surface coating, but also abandons the pollution caused by chemical plating problems; it is an excellent green method.

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