*Large sputtering coating plant working with a mode of scan

Weiyuan Guo*

National Astronomical Observatories/Nanjing Institute of Astronomical Optics and Technology,CAS,Nanjing 210042,P.R.China

ABSTRACT

Introduction to design thought of a large vacuum sputtering coating plant for astronomical telescope .The coating plant is square and all working cells are installed on a holder inside the chamber. When the plant door open, the holder with working cells is hauled out of chamber, then maintaining, repair and installing mirrors are very easy.

Metal film and dielectric film are made with DC and RF magnetron sputtering respectively. The largest diameter of mirror is 1600 mm and the diameter of sputtering target is 160 mm. The whole mirror is coated by the polar coordinate scanning through computer control.

There are three advantage: large mirror is sputtered with small power supply, so the cost is saved; By computer controlling working parameter of scanning, better uniformity can achieve; scanning sputtering can correct the mirror surface.

Key words: Film technics, coating plant, magnetron sputtering

1. INTRODUCTION

In the process of manufacturing astronomical telescope mirrors the coating technics is a crucial one. Usually, we need a coating with high adhesion and excellent uniformity. At the same time the reflectivity and the spectral characteristic of coating are also extremely important for the telescope performance.

Traditionally, we use the vacuum evaporation for coating, with Al or Ag as a reflecting coat and then deposit a protective coat. In order to improve the quality of coat, magnetron sputtering coating is widely used now. For example, VLT, Gemini and several 8 meter telescopes are coated using magnetron sputtering technics[1]. Compared with evaporated coating technics, the coat used sputtering coating technics will have better compaction, the higher reflectivity, the better adhesion.

The coating plant is manufactured by Lanzhou Vacuum Equipment Co.Ltd.

*wyguo@niaot.ac.cn; fax 86-25-85405562

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2. MAGNETRON SPUTTERING COATING PLANT

2.1 Magnetron Sputtering Fundamentals

The cathode sputtering technique have existed for more than 100 years. When the target is connected to negative high voltage, a glowing plasma forms just above the target surface. Positive Argon ions produced in the plasma by collision of electrons with argon atoms are accelerated toward the negative-charged target. When the fast-moving ions collide with the target, free atoms of target material are expelled. The object to be coated, the substrate, for example a mirror , is mounted in front of the target and some of the free atoms land on the substrate, building a thin film. Modern sputtering plant uses magnetron sources, in which plasma is confined by a magnetic field. By the use of this magnetic system behind the target, there is a very dense plasma, where the secondary electron is forced by the Lorentz force to stay in a circular path. Through this, the Ionization efficiency is increased leading to higher density of ions, which in turn increases sputtering rate.

Figure 1 is a schematic representation of circular plane magnetron sputtering target. The partial lines of magnetic force form an electronic course on the target surface and the electrons are confined in the course. The Ionization efficiency is increased greatly, therefore the sputtering efficiency will be enhanced greatly. Big dimension is not suitable for the circular target and it is only generally used in the laboratory for small coating plant.

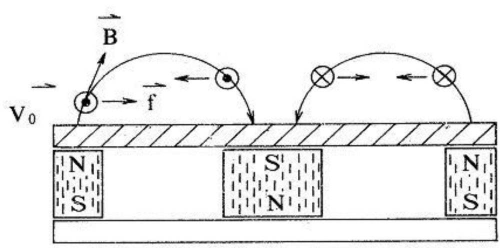

Figure.1 Schematic representation of circular planar magnetron sputtering target

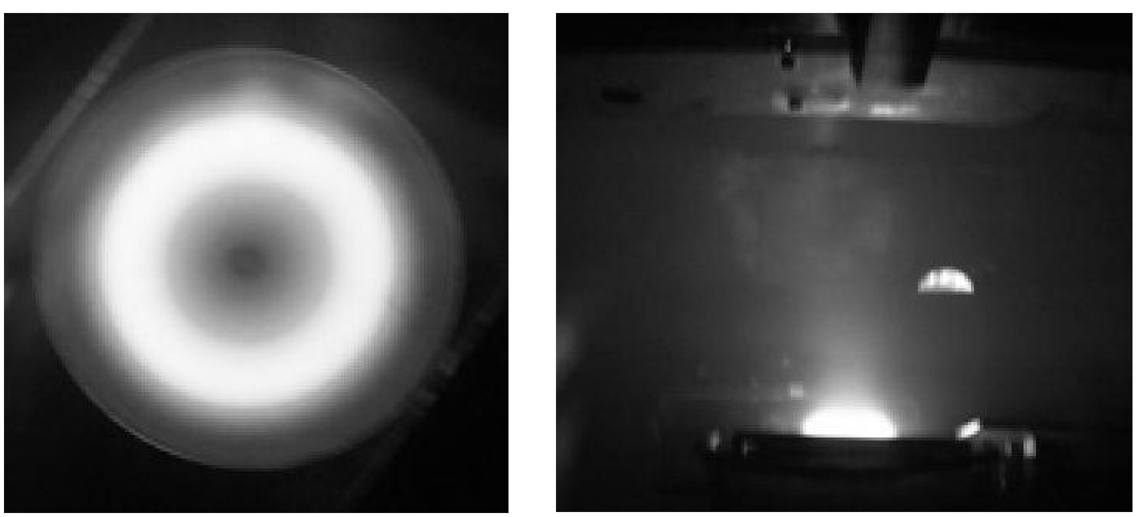

Figure.2 Working mode of circular planar magnetron sputtering target

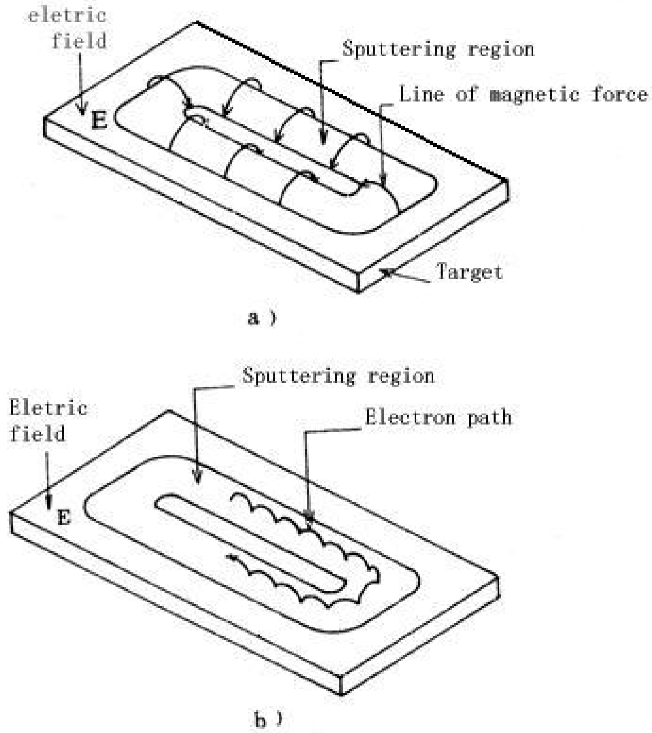

Figure.3 Schematic representation of rectangular magnetron sputtering target

Figure 3 is the schematic representation of rectangular magnetron sputtering target. The dimension of the target's length can achieve several meters, which is suitable for the large production plant. Figure 4 is the working mode of rectangular magnetron sputtering target.

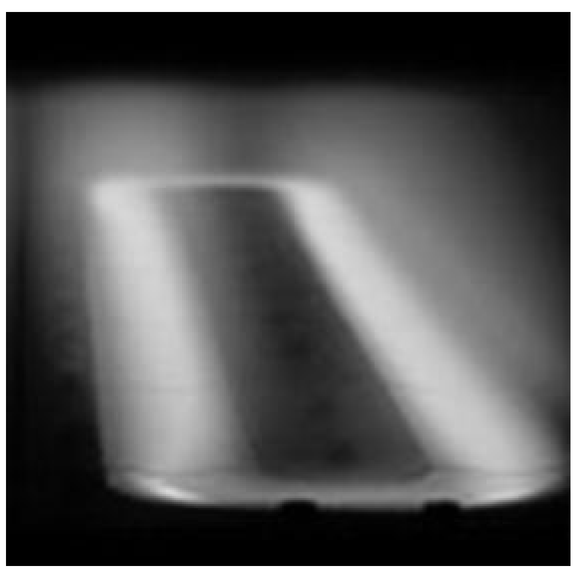

Figure.4 Working mode of rectangular magnetron sputtering target

2.2 Magnetron sputtering coating plant used for coating astronomical telescope

Figure 5 is the schematic representation of an 8 meter telescope coating plant[2]. It uses two rectangular targets crossing the radius for sputtering coating Ag and protective film respectively on the mirror surface. Because the line speed of each point relativized by the target in the radial direction of the circular mirror surface is different, the film thickness of the mirror surface is adjusted by a pair of anti-revolving shaped shutters which make the film uniform.

There is three problems here: 1.It is just suitable for the mirror that there is a hole in the middle; 2.Because of matching large area of the target, the power of sputtering source will be very big. 3. Some film materials are consumed by the shaped shutters. That will cause the waste.

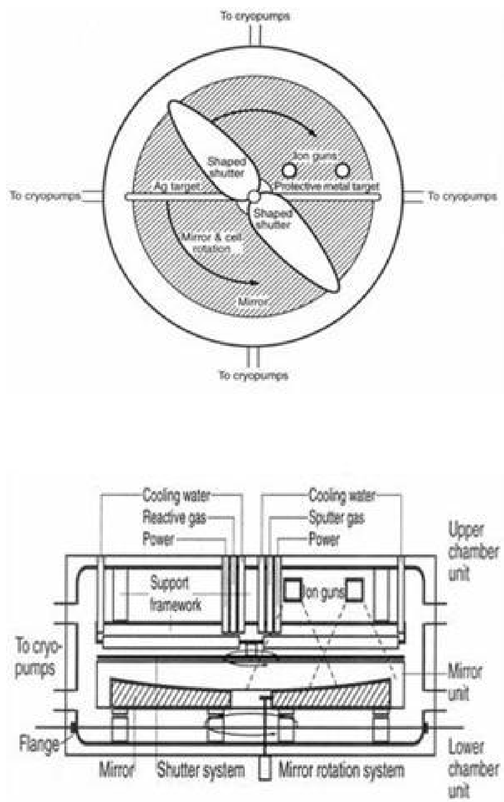

Figure.5 Schematic representation of an 8 meter telescope coating plant

3. STRUCTURE OF A NEW COATING PLANT

We have recently made a magnetron sputtering plant(Figure 6). This plant doesn’t use the rectangular target, but by using a circular planar magnetron sputtering target with a mode of scan it can carry out coating on the mirror surface. That will make the problems we mentioned improved.

Working fundamentals of the new coating plant read as follows: the mirror prepared for coating is placed on the circular workpiece turnplate, which will rotate when coating, above the vacuum chamber; The circular planar magnetron sputtering target which is below the mirror will move linearly along the diameter direction of the turnplate when coating. The mirror will be coated by a ring and a ring in turn.

There is the same problem of different line speed, so the process of scanning coating need to be controlled by the computer. According to the theoretical calculation, the moving speed of the target and the velocity of the workpiece are adjusted at any moment, then uniform film can be obtained. Different thickness of the film will be obtained by changing the moving speed of the target.

An essential condition is that the sputtering rate must be stable and this may be guaranteed by collocating sputtering source with high quality.

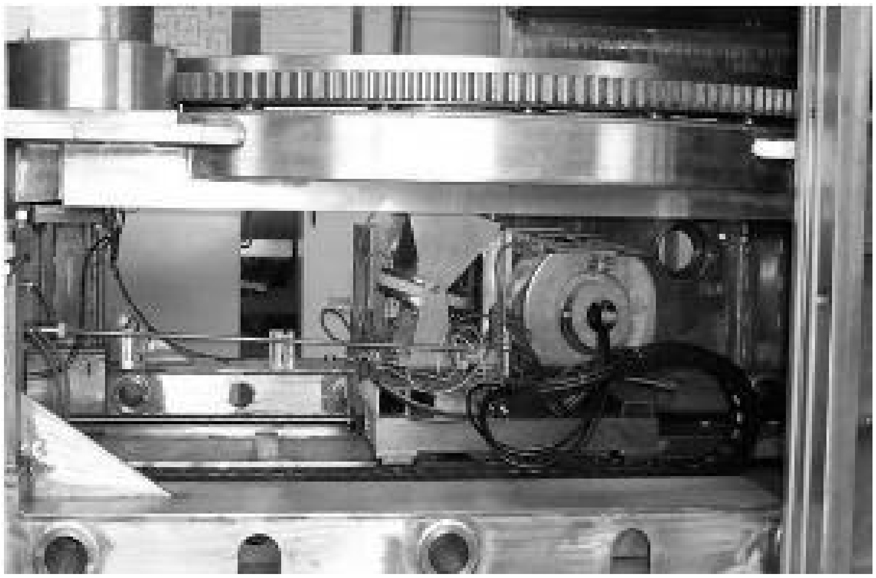

Figure.6 Internal structure of the new coating plant

This method has some advantages as follows:

(1). It can be applied to the mirror that there is no hole on the surface, for instance sub-mirror of LAMOST. Because the small target can move to the center of the workpiece.

(2). Scanning process controlled by computer realize the uniform coating. Don't need the shaped shutters to adjust the uniformity of film thickness. Thus, we have the more confidence to control the uniformity of film thickness. At the same time expensive target material can be saved.

(3). The area of circular planar magnetron sputtering target is very small, so the matching electrical source is only 2.5KW. The sputtering source with high quality is very expensive and the price is approximately in proportion to output power. Obviously, the larger coating plant used this way, the more money will be saved..

(4). Installing the suitable ion source or the smaller sputtering target on the moving machine can realize two different mirror figuring technic or fabricate aspheric mirror.

The mechanical scanning way has two coordinates: the Cartesian coordinates or the polar coordinates. Compared with the Cartesian coordinates, the structure of the plant used the polar coordinates will be very simple. This coating plant uses the polar coordinates. If necessary, it can be refitted as the Cartesian coordinates.

Not only is the film quality and uniformity required, but also metal film and dielectric film can be coated successively in once coating process. In other words, this plant should have DC and RF sputtering function and collocate multi-targets.

At the same time multi-targets are installed in the vacuum chamber, which is difficult in the technic. Ultimately four targets are installed on a rotated drum, facilitating switching. In the ordinary course of events, the switching of targets is also controlled by computer. Each target has its own specifically number. When a target completes coating, the computer which will accord to the program in advance lets another target turn to the sputtering position, carrying out the next coating.

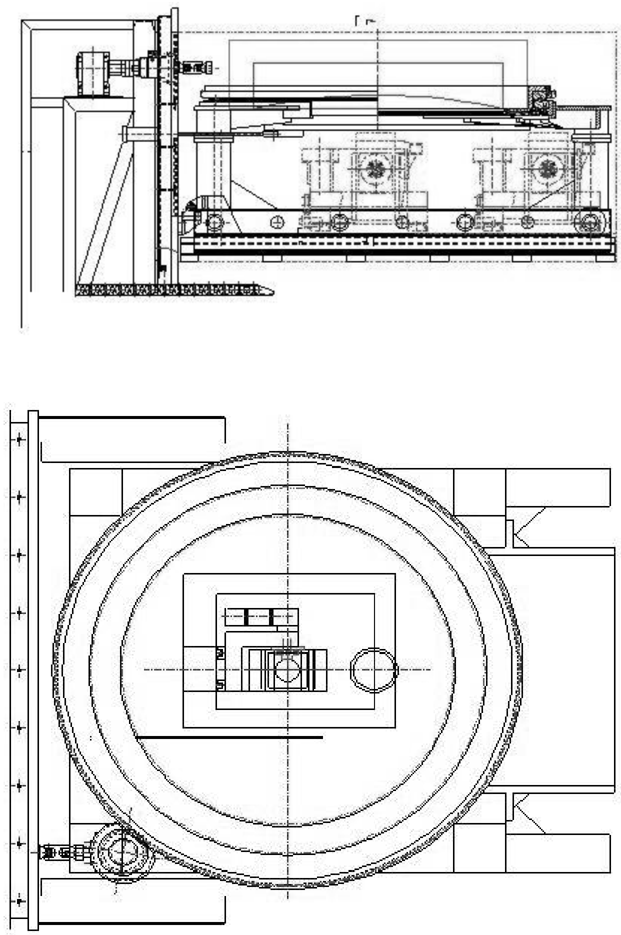

Figure.7 Blueprint of the new coating plant[5]

Because the inclining angle of each target in the coating process can change continuously, according to the figure of mirror, the target can automatically adjust its gradient. At the same time it can correspondingly adjust the altitude to guarantee that the target surface points to the normal direction of the mirror surface to carry out coating with the same target-substrate distance.

Prepare to use 2or3 dielectric targets and series of antireflection film will be acquired using the RF magnetron sputtering method on the metal reflection film to increase the reflectivity. According to the analysis of Hass[3], the reflectivity of Al film can be increased greatly only using two pair of dielectric film.

In order to guarantee the film quality, the coating plant uses the cryopump to obtain the high vacuum, so this guarantees the vacuum environment containing no oil. Considering the degree of cleanness on the mirror surface has a great influence on the film quality, an ion source is installed in the vacuum chamber for cleaning. At the same time the high-voltage ion bombardment function, which is generally used by coating plant, is also retained for cleaning the internal surface of the vacuum chamber.

The plant has four gas inputs paths which are controlled by the gas mass flowmeter.

4. USE COATING METHOD TO REVISE LOW FREQUENCY ERROR OF MIRROR

Because this coating plant uses the scanning coating method and the controlling precision of moving is high enough, if the ion source used for cleaning mirror which is installed on the moving machine in the vacuum chamber is changed into the one that has high stability and excellent distribution of the ion beam, working with the controlling software of the computer, it can carry out the ion beam figuring[4].

4.1 Data processing of the ion beam figuring

The ion beam figuring wipes off the part which is higher than the standard figure. As the figure 8 shows, after the figure error distribution of mirror is acquired by measuring, a certain lowest point of the error data is regarded as the reference point, which is made superposition with the standard figure. The mirror material above the standard figure is the part which theoretically needs to be removed.

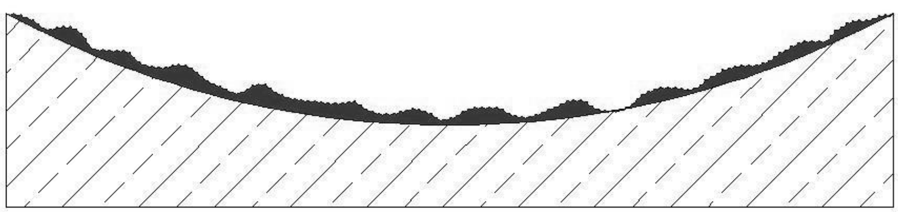

Figure 8 Schematic diagram of the part wiped off by ion beam figuring

4.2 Data processing of using "coating figuring" method to revise the mirror figure

Contrary to the thought we have mentioned, we can use "coating figuring" but not "cutting" to revise the figure of the mirror surface. The data processing method is different from the one of the ion beam figuring.

Referring to the figure 9, in the data of mirror figure error, a certain highest point is chosen for superposing the standard mirror surface figure and then the sunken part below the standard mirror figure is filled up with a certain material. That will make it inosculate with the standard mirror figure to the utmost and the goal of revising mirror figure can be achieved.

In order to enhance the precision of "coating figuring" method, a smaller target is prepared to use.

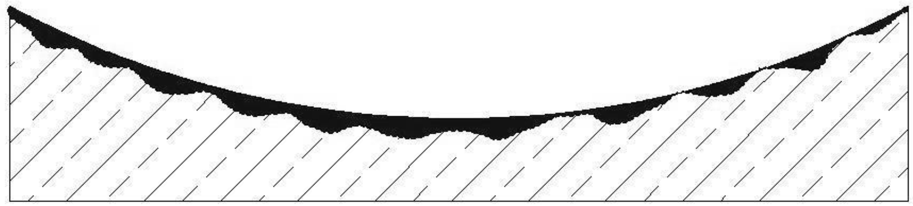

Figure 9 Schematic diagram of the part filled up by "coating figuring"

4.3 Calculation of the "coating figuring" method

Supposed E(x,y) is the function of the mirror error distribution, every element value here is the negative and the data processing method is contrary to the one of the ion beam figuring technics; F(x,y) is the "coating function" of small magnetron sputtering target. Namely the target relativized the substrate carries on coating in a state of stillness to obtain the distribution of film thickness. Then the sputtering rate of each point can be acquired by the distribution of film thickness; T(x,y) expresses the staying time E(x,y) of the target central point on the mirror surface. The relationship of them is expressed by the following formula:

$$E(x,y)=F(x,y)**T(x,y) \tag{1}$$

If we obtain E(x,y) and F(x,y) by measuring, then T(x,y) will be obtained by the counter-convolution operation. The three functions will be carried on Fourier transformation respectively:

$$E(x,y) \rightarrow e(u,v)$$

$$F(x,y) \rightarrow f(u,v)$$

$$T(x,y) \rightarrow t(u,v)$$

In the frequency region, formula (1) will be transformed as:

$$e(u,v)= f(u,v)\cdot t(u,v) \tag{2}$$

According to the formula (2), we can get:

$$t(u,v)= e(u,v)/ f(u,v) \tag{3}$$

After t(u,v) is acquired according to the formula (3), t(u,v) will be carried on Fourier transformation:

$$t(u,v) \rightarrow T(x,y) \tag{4}$$

According to the staying time table T(x,y), the computer accurately controls the moving of the target relativized the mirror surface. The hollow part of the mirror surface will be coated and ultimately the figure precision of the mirror surface will be enhanced.

As a part of mirror surface figuring, the mirror surface revised can keep stabilization. Even if it needs to be recoated the reflection film, the film will not be affected. Therefore the film which has good compatibility and stability should be coated on the mirror surface, for instance SiO2.

5. SUMMARY

The sputtering source's moving relativized the substrate can make the small target complete the coating of big-caliber mirror surface. Multi-targets which are easy to switch can be fitted for coating series of anti-reflection film. Not only can the film thickness uniformity be enhanced, but also mirror surface error can be revised.

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