

Metallic Mirror Experiment with 1.6 m Coating Machine

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ABSTRACT

We have produced a series of reflective mirrors using the newly installed 1.6m evaporation chamber at the Nanjing Institute of Astronomical Optics and Technology (NIAOT) of the National Astronomical Observatories of China. The main task of this equipment is to coat the mirrors of the LAMOST. The chamber have thermal evaporation system, electron beam source, ion beam source, quartz crystal deposition controller and optical monitoring system, so can evaporate all kinds of metal and oxide film and effectively control film thickness. Now, we have utilized this chamber to aluminize the mirrors of LAMOST primary mirror, the average reflectivity is above 89% in the wavelength range from 370nm to 900nm. Recently, we have completed the enhanced silver reflector experiment, by controlling the dielectric layers optical thickness, the reflectivity is increased from 370nm to 400nm. The average reflectivity of enhanced silver reflector is above 97% in the wavelength range from 370nm to 900nm.

Keywords: coating, reflectivity, uniformity, copper-based silver intensified mirror

1. INTRODUCTION

LAMOST is a meridian reflecting Schmidt telescope, its MA (Schmidt corrector plate) is 5.7m long and 4.4m wide which is composed of 24 submirrors and MB (spherical primary mirror) is 6.67mX6.05m with curvature radius of 40m which is composed of 37 submirrors. Hexagonal submirror is 1.1m in diagonal and 25mm (MA), 75mm (MB) in thickness, which are all aluminized. As part of the discussions of the steps of coating ought to being simple and the old aluminum being removed conveniently, the idea of aluminizing was proposed.

The performance goals are to produce aluminum coatings with the following characteristics:

1. Film thickness is in the range of 1000Å-1500Å.
2. The uniformity of thickness distribution is within 5%.
3. The absolute reflectivity of 370nm-420nm is above 82%; 420nm-700nm above 86%; 700nm-900nm above 80%.
4. durability of the film: adhesive tape(20mm wide) is pressed onto the aluminum coating and peeled off rapidly again, if no material is removed then the coating passed.

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In order to realize 1.6m coating chamber for large mirrors, there are many important aspects to consider. The thickness uniformity and high reflectivity over the wide range of wavelength are the most important. So the location of evaporation system and substrate, high vacuum, low contamination, high deposition rate and durability of the film should be taken into account¹⁻⁷.

2. SYSTEM DESCRIPTION

The 1.6m coating machine have the same two sets of vacuum systems: each of them has oil diffusion pump as high vacuum system, mechanical pump and roots pump as rough vacuum system. Refrigerated baffle of the diffusion pump can prevent the oil steam into the chamber effectively. Figure 1 illustrates the layout of the vacuum system.

The chamber have thermal evaporation system, electron beam source, ion beam source, quartz crystal deposition controller and optical monitoring system, so can evaporate all kinds of metal and oxide film and effectively control film thickness.

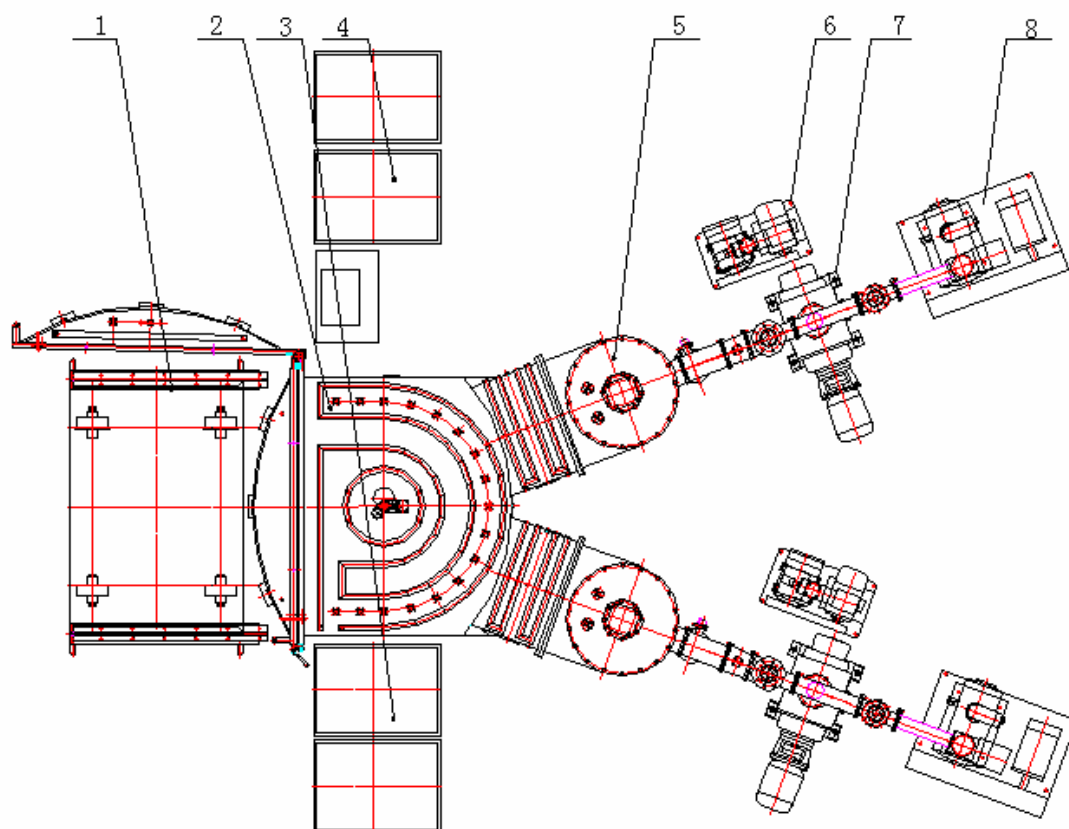


Figure 1: Layout of the vacuum system

1. loading vehicle 2. chamber 3. electron beam source control 4. vacuum control 5. diffusion pump 6. maintaining pump
7. roots pump 8. mechanical pump

3. COATING UNIFORMITY

Based on the following assumptions, film thickness distribution of theory can be expressed:

1. The pressure in chamber is low enough to ensure that no collisions occur among the vapor and air molecules.
2. All vaporizable molecule coming to the optical surface form thin film and the film density is same as solid.
3. The emission characteristic of vapor source is no change with time.

Then the thickness of a growing film at a point on a substrate surface can be determined with the following equation:

$$t_p = C \frac{\cos^n \phi \cdot \cos \theta}{r^2} \quad (1)$$

where C is constant, r is the distance between the point and vapor source, ϕ is the angle between the vapor stream and the normal to the source, $\cos^n \phi$ expressed evaporation character of the source, θ is the angle between the vapor stream and the normal to the substrate surface.

For the rotating substrate, the thickness can be expressed:

$$\langle t_p \rangle = \frac{1}{\pi} \int_0^\pi C \frac{\cos^n \phi \cdot \cos \theta}{r^2} d(\omega t) \quad (2)$$

where ωt is the azimuth, the relative thickness at any point on the substrate is given by

$$\frac{\langle t_p \rangle}{\langle t_0 \rangle} = \frac{\int_0^\pi C \frac{\cos^n \phi \cdot \cos \theta}{r^2} d(\omega t)}{\int_0^\pi C \frac{\cos^n \phi_0 \cdot \cos \theta_0}{r_0^2} d(\omega t)} \quad (3)$$

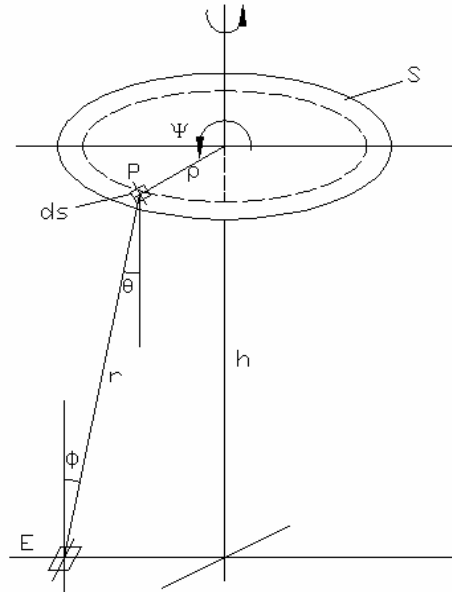


Figure 2: Geometry of the 1.6m coating chamber

Emission characteristics of filament can be approximated as a point source that follows a cosine function, $\cos\Phi$, then Equation (3) can be transformed into

$$\frac{t_p}{t_0} = \frac{(h^2 + L^2)^2 (h^2 + L^2 + \rho^2)}{\left[(h^2 + \rho^2 + L^2)^2 - 4L^2 \rho^2 \right]^{\frac{1}{2}}} \quad (4)$$

where L is the evaporation source offset from the rotation, h is the rack height and ρ is the rack radius. Figure 2. shows the geometry of the 1.6m coating chamber.

For the 1.6m coating chamber, when L is 700mm and h is 950mm, the theoretical thickness distribution is within 5% and illustrated by figure3.

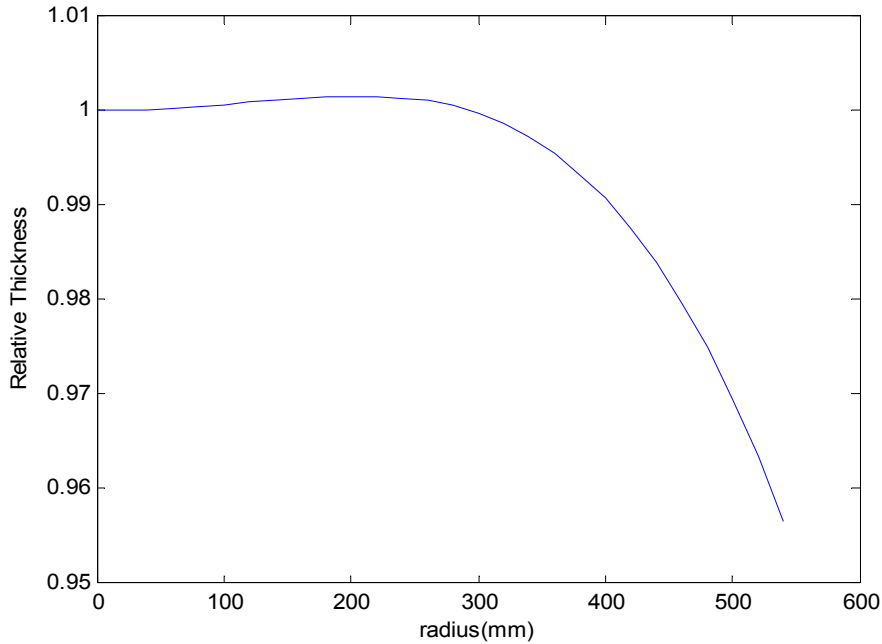


Figure 3: Theoretical thickness distribution for L=700mm and h=950mm

4. REFLECTIVITY

Reflectivity value for the samples aluminized simultaneously with the mirror is shown in figure 4. The diameter of sample is 50mm, the cleaning procedures and the material are same with the mirror. The average reflectivity is above 89% in the wavelength range from 370nm to 900nm. Figure 4 shows the reflectivity of the sample.

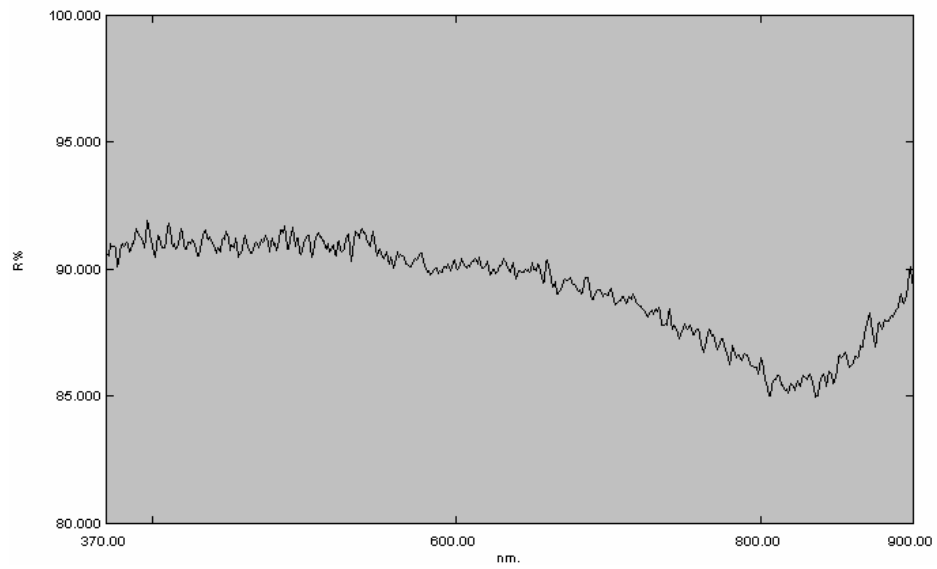


Figure 4: The reflectivity of the sample aluminized simultaneously with the mirror Mb21

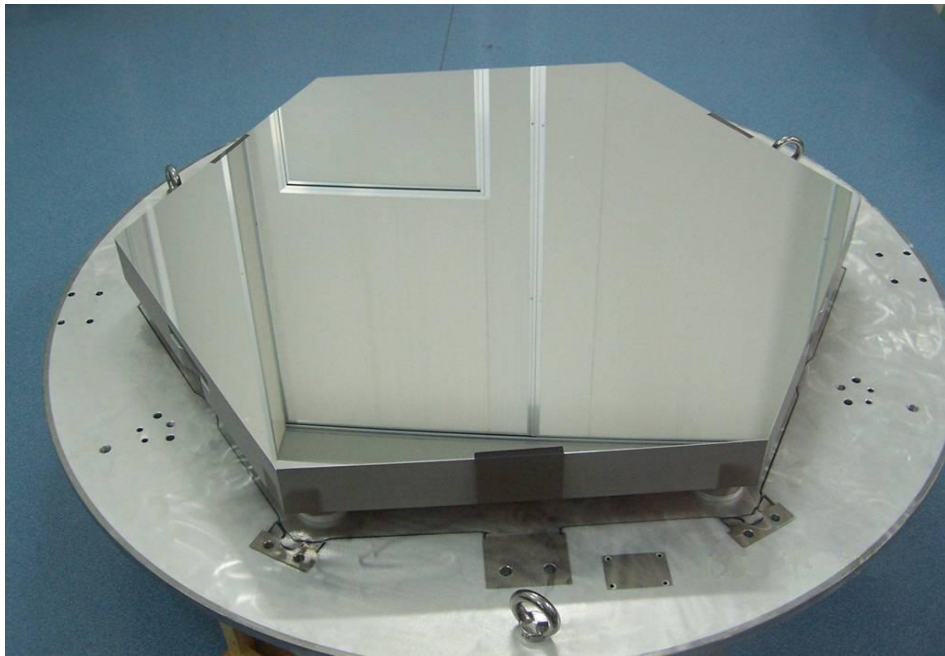


Figure 5: The submirror of Mb21 completed aluminum coating

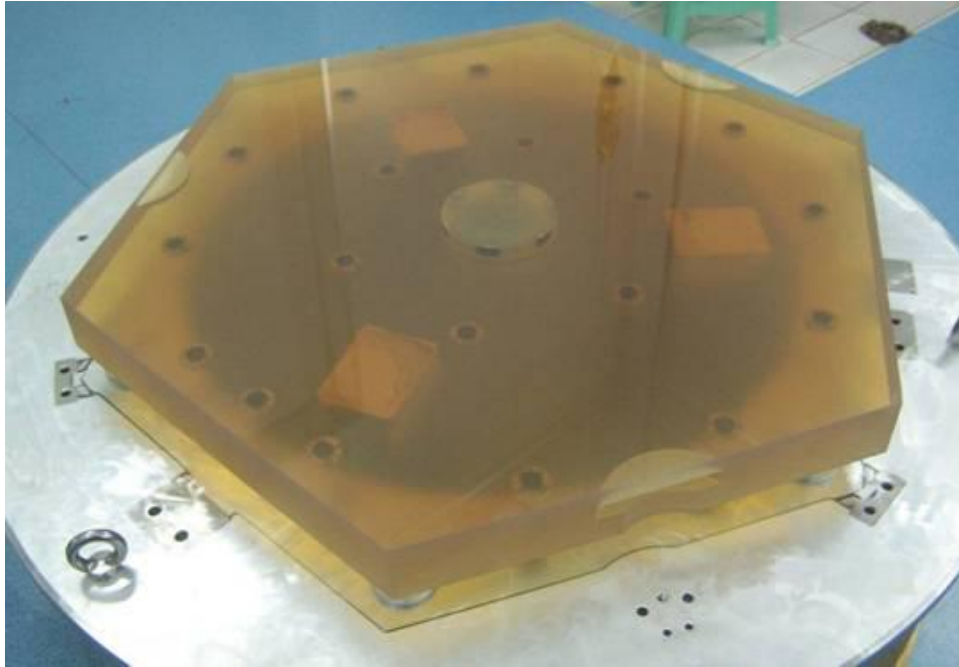


Figure 6: One submirror of LAMOST

5. EXPERIMENT OF SILVER REFLECTOR

Silver reflector has higher reflectance than aluminum in the visible and infrared portions of the spectrum, but silver is susceptible to tarnishing and corrosion and has poor reflectance in the ultraviolet^{8,9}. By arranging appropriate protective coating layers and floor layers, improve the environmental resistance and reflectance in the ultraviolet of silver reflector, and make silver reflector fit requirements of the astronomical telescope even more.

We have utilized the 1.6m chamber to develop copper-based silver intensified mirror. By controlling the dielectric layers optical thickness, the reflectivity is increased from 370nm to 400nm in the ultraviolet. By adding the copper layer beneath the silver, the environmental resistance is improved. The average reflectivity of enhanced silver reflector is above 97% in the wavelength range from 370nm to 900nm. The design was then

Air / HLH0.78M Ag(100nm) Cu(20nm) Cr(10nm) / glass

Where H indicates a quarterwave of Ti3O5, L is a quarterwave of SiO2, and M is a quarterwave of Al2O3.

Figure 7 is the calculated performance of silver reflector and figure 8 shows the reflectance of the sample.

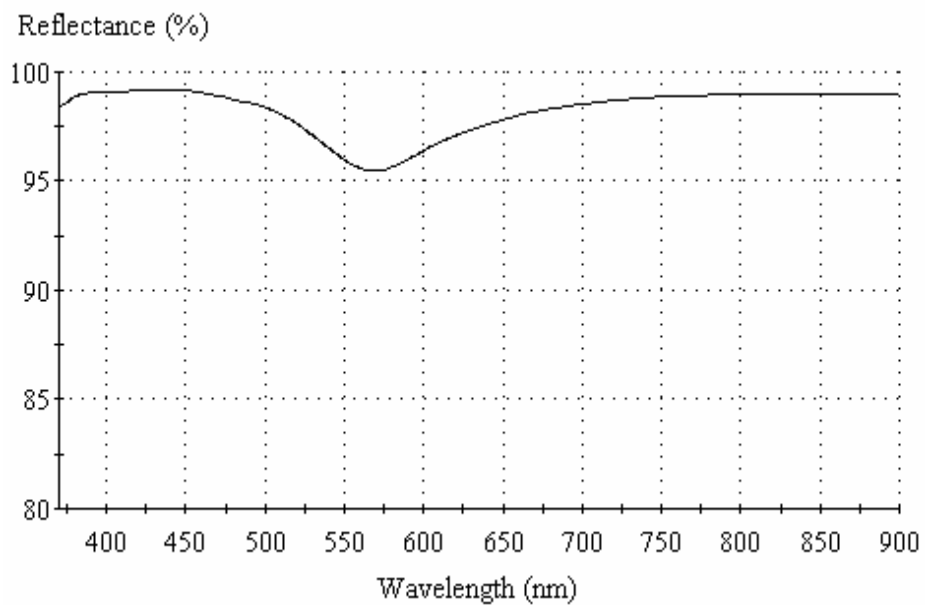


Figure 7: The design reflectance of silver reflector

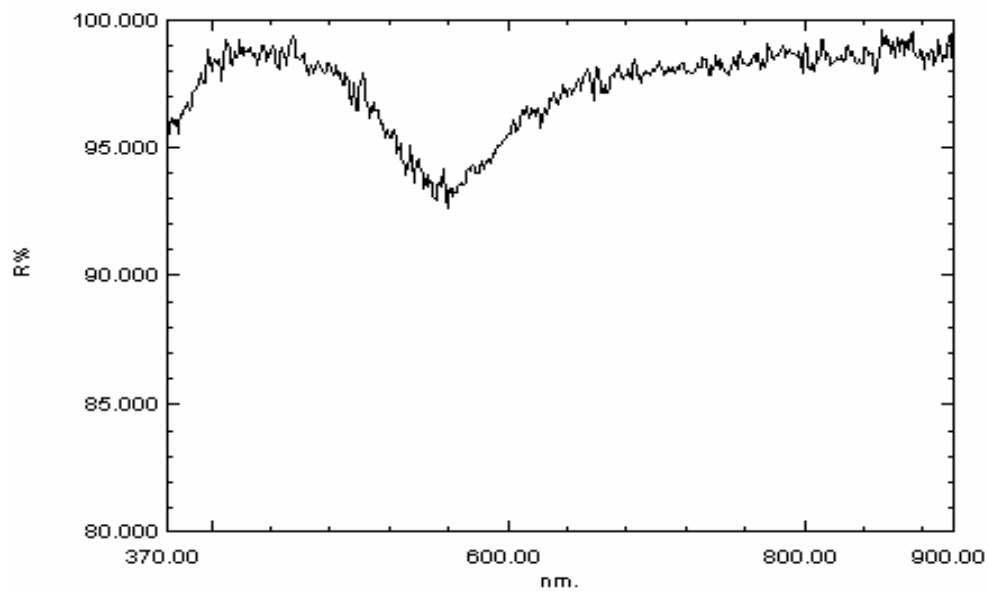


Figure 8: The sample reflectance of silver reflector

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