

TWO LAYERS ANTIREFLECTION COATING FOR LASER

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We have fabricated a bi-layer (SiO and MgF₂) anti-reflection coating for fixed wavelength laser on synthetic fused silica and observed its performance. These coatings are found very hard, durable, easy evaporation, adherent and a peak transmission 99.9% at the design wavelength at normal incidence. Coatings can stand a long time without any deterioration even in the high power Copper Vapor Lasers (CVL) upto 300 watts. These coatings are produced by the thermal evaporation in high vacuum and the optical thickness of the each layer is quarter wave controlled by optical monitoring system.

Keywords: Antireflection, Transmission, Coating, Thin film coating, Evaporation, Vacuum

1. Introduction

Anti-reflection (AR) coatings are usually used for laser optics to enhance transmission and reduce reflection losses from the surfaces of transparent optics like lenses and windows. The AR coatings for the optics of lasers in visible and near infrared range of spectrum consist of two or more layers of materials having different refractive index and of optical thickness quarter or non quarter wave stacks [1-3]. For this purpose different combination of non-absorbing dielectric materials are generally used for increasing the transmission of laser from the optic surfaces so that $R = 1 - T$, where R and T are reflectance and transmittance respectively. A variety of methods have been designed for this purpose. In two-layer system one can choose different combination of optical materials and layer thickness for anti-reflection coating at given wavelength. The choice of the materials for desired optical performance depends upon the deposition process, uniformity and cost. Here we have selected SiO and MgF₂ [4] for two layers coating on each side of the optics. For zero reflection (max transmission) each layer should be one-quarter wave-thickness and due to economic reasons thermal evaporation process in a vacuum is used [5-7]. SiO have good mechanical and chemical properties and extensively used for protective layers on first surface mirrors. Its evaporation temperature is lower than silicon and

silicon dioxide and film is uniform and adherent to the substrate even on unheated substrate and has thermal stability upto 400 C⁰ [8]. Its refractive index (1.8 to 1.9) depends upon the evaporation conditions and transparency range is 0.7-9 μm [9]. MgF₂ (n=1.38 to 1.40 at 0.55μm in air depending upon the temperature of the substrate) is the most common material for the anti-reflection coating and it is hard resistant against humidity and high tensile stress (cracking) [9]. Its transparency range is 0.13 - 8μm [10] and is readily evaporated by common thermal evaporation process (see Table 1).

Table 1. Some physical properties of SiO and MgF₂.

| Properties | Values | |
|------------------------------|---------|------------------|
| | SiO | MgF ₂ |
| Index of refraction | 1.8-1.9 | 1.38-1.40 |
| Transparency range (μm) | 0.7-9 | 0.13-8 |
| Density (g/cm ³) | 2.1 | 3.1 |
| Melting Point (°C) | 1705 | 1266 |
| Boiling Point (°C) | 1880 | 2239 |

2. Substrate Qualities and Cleaning Process

The performance of the coating depends upon substrate quality like polishing, finishing and cleaning. The surface preparation prior to coating is essential for laser windows and good quality

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surface will be helpful in drawing the final results like quality and performance of the coating. The plane windows were polished to $1/4$ of a wavelength over the central 80% of aperture and parallelism of the two surfaces is 5-arc sec; these parameters were measured by Zygo mark-IV interferometer (see Table 2). Moreover the cleanliness of the surface of the substrate is also important for the adhesion of the film to the substrate. Our cleaning process consist of cleaning the optical surfaces with optical grade acetone followed by ultrasonic agitation for about 15 minutes and then thoroughly rinsed with deionized water. The surface was blown dry with nitrogen. The above cleaning process was performed in dust free close portable hood and immediately loaded into the coating chamber.

Table 2. Specification of synthetic fused silica substrate

| Specification | Value |
|--|---------------------------|
| Surface flatness. | $\lambda/4$ |
| Parallelism of faces | 5 arc sec |
| Absorption Co-efficient of the blank substrate | $< 0.002 \text{ cm}^{-1}$ |

3. Experimental Procedure

The evaporation was performed in a 48 cm diameter vacuum chamber with oil pumped system having liquid-nitrogen cold trap. Substrate holder is above the base plate and a substrate of diameter upto 39.6 cm can be coated. All electrical and vacuum connections are through the base plate. There are two electrodes located on the side of the base plate. Molybdenum and Tantalum boats as crucibles from Balzers were used for the materials SiO and MgF_2 respectively. The two shutters near the boats were used to cover them to avoid the contamination during the warming up and at the

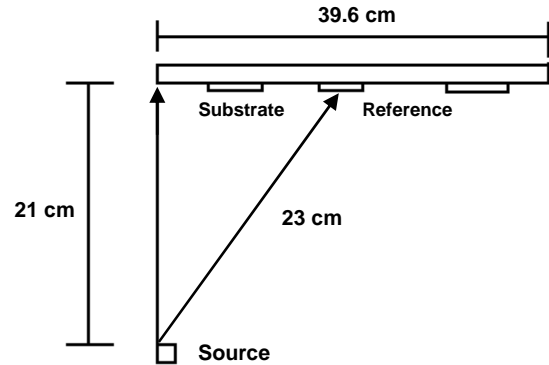


Figure 1. Geometry of deposition.

time of termination of coating at required thickness.

The substrates to be coated were placed in holes made in a flat [11] aluminum circular sheet at a distance of 21 cm above the thermal sources as shown in Fig 1. The system was evacuated and subjected for glow discharge for about 5 minutes and then heated the substrates at 150 C° before the evaporation. At the time of evaporation the vacuum was about $(1-3) \times 10^{-6}$ torr and the speed of the work holder was 92 revolutions per minute. A small amount of materials was allowed to evaporate for degassing by placing the shutter on it and after some time it was allowed to deposit on the cool surface of the substrates. The thickness of the film was controlled optically. In this case SiO was first evaporated and then MgF_2 on both sides of the fused silica substrate as shown in Fig 2, the optical thickness of the each layer was quarter wavelength.

The interior of the chamber and accessories were covered with thin aluminum foils and after a few depositions this was replaced. In this way we can avoid the dust particles from the previous evaporation to settle on the surface of the substrate and cause scattering.

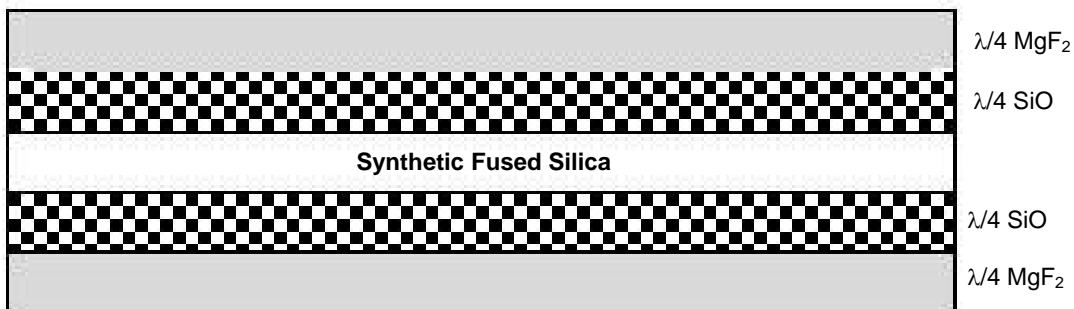


Figure 2. Antireflection coating on synthetic fused silica

- P.S. Power Supply
- L Lamp
- C Chopper
- W Entrance Window
- M Monochromator
- P Photomultiplier Tube
- A Lock in Amplifier
- R Recorder

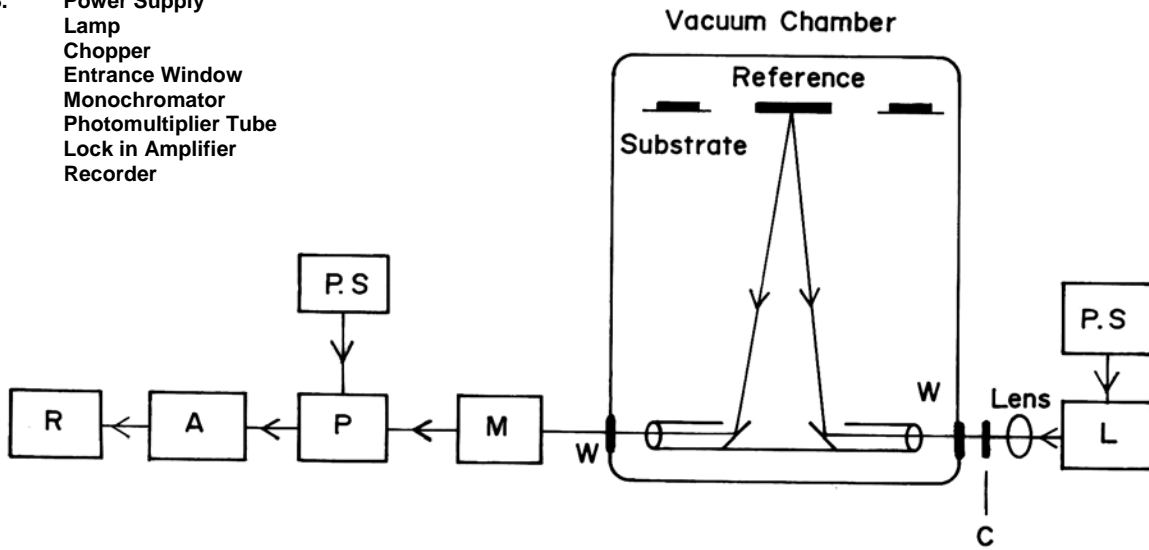


Figure 3. Thickness monitoring system

4. Monitoring

An accurate monitoring system for the measurement of the thickness of the layer is very essential, as well as to observe the changes in the refractive indices of the film during deposition [12,13]. For monitoring the thickness of the film during the evaporation a reference substrate was mounted in the center of the chamber, its one side was grounded and the other side plane. A visible collimated light is used whose output beam is chopped and falls on the reference which direct the reflected light to monochromator at 550 nm coupled with photo multiplier tube [14] connected to the chart recorder through auto lock amplifier for damping the vibration noise (Fig 3).

As the coating proceeds the intensity of the out coming beam changes with the increase of the film thickness. This change is monotonically to a maximum at quarter wave optical thickness if the refractive index of the film is greater than the refractive index of the substrate and to a minimum if the refractive index of the film is less than that of the substrate. The rate of evaporation of the both materials was monitored by the oscillating quartz crystal [15-17]. The rate of evaporation and time is given in Table 3.

First SiO was deposited on the substrate, upon reaching the first maximum on the chart recorder the deposition was stopped, then MgF₂ with low index was conducted and at first minimum the coating was interrupted.

Table 3. A comparison of deposition rate and evaporation time.

| Materials | Deposition rate (nm/s) | Evaporation source | Evaporation time (Min) |
|------------------|------------------------|--------------------|------------------------|
| SiO | 0.7 | Molybdenum | 3.15 |
| MgF ₂ | 0.5 | Tantalum | 4.30 |

5. Measurement

The coated substrates were measured by an automated scanning shamdu uv-visible recording spectrophotometer uv-160 and it was observed that the transmission of the light was 99.9% at 550 nm as shown in Fig 4.

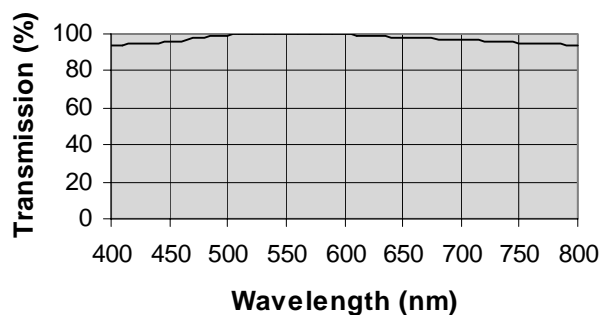


Figure 4 Transmission Curve

6. Conclusions

We have studied the transmission behavior of laser through the coated windows with two materials SiO and MgF₂ deposited on the both

sides of synthetic fused silica windows of each quarter wavelength thickness. Both materials can easily be evaporated and forms hard and adherent coating [18,19] that gives high quality optical performance. It was also observed that coating could withstand environmental conditions and have improved damage resistance to lasers [20] and durable [21].

The thickness of the layers was controlled optically and in this way we can reproduce anti-reflection coating several times.

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