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Design of high reflective and antireflective mirrors using ZrO_2 and SiO_2 materials in IR region

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Abstract
Stacks of quarter wave and non-quarter wave multilayer coatings are used for alter the optical properties of a substrate, like increasing or decreasing reflection. Anti-reflective coatings and highly-reflective coatings are two examples that are widely used. Thin film technology is also used to construct hot and cold Mirrors (Dichroic) High pass Filters and Low Pass filters, Beam Splitters, Interference Filters, Neutral Density Filters, Polarizing Beam Splitters, Transparent Conducting Coatings. In this study dielectric high reflective and antireflective mirrors are formed with reflectivity above 99% and transmission in antireflective mirrors also greater than 99% at 1064 nm in infra-red region with ZrO_2 and SiO_2 materials. Reflection and transmission is measured by spectrophotometer.

Keywords: Quarter wave, coatings, beam splitters, neutral density filters, dielectric

Introduction

The vast majority of optical components are made of various types of glass, and most are coated with thin layers of special materials. The purpose of these coatings is to modify the reflection and transmission properties of the component surfaces [1]. Whenever light passes from one medium into a medium with different optical properties (most notably refractive index), part of the light is reflected and part of the light is transmitted. The intensity ratio of the reflected and transmitted light is primarily a function of the change in refractive index between the two media, and the angle of incidence of the light at the interface. For most uncoated optical glasses, 4-5% of incident light is reflected at each surface. Consequently, for designs using more than a few components, transmitted light losses can be significant. More important are the corresponding losses in image contrast and lens resolution caused by reflected ghost images (usually defocused) superimposed on the desired image [2]. Applications generally require that the reflected portion of incident light approach zero for transmitting optics (lenses), 100% for reflective optics (mirrors), or some fixed intermediate value for partial reflectors (beam splitters). The only suitable applications for uncoated optics are those where only a few optical components are in the optical path, and significant transmission inefficiencies can be tolerated. In principle, the surface of any optical element can be coated with thin layers of various materials (called thin films) in order to achieve the desired reflection/ transmission ratio. With the exception of simple metallic coatings, this ratio depends on the nature of the material from which the optic is fabricated, the wavelength of the incident light, and the angle of incidence of the light (measured from the normal). There is also polarization dependence to the reflection/transmission ratio when the angle of incidence is not normal to the surface [3]. A multilayer coating, sometimes made up of more than 100 individual fractional-wavelength layers, may be used to optimize the reflection/transmission ratio for a specific wavelength and angle of incidence or to optimize it over a specific range of conditions. Today's multilayer dielectric coatings are remarkably hard and durable. With proper care and handling, they can have a long life. In fact, the surfaces of many high index glasses that are soft or prone to staining can be protected with a durable antireflection coating. Several factors influence coating durability [4, 5]. Coating designs should be optimized to minimize thickness and reduce mechanical stresses that may distort the optical surfaces or cause detrimental polarization effects. Great care must be taken in coating fabrication to produce high-quality, non granular, even layers.

In this study thin films of ZrO_2/SiO_2 are formed for 99% reflectivity and transmission and same have been achieved by using proper design.

Experimental

High reflective mirror with a greater ability to withstand high incident laser fluence is constructed by alternate coatings of quarter wave optical thickness of zirconium and silicon oxide (one of the higher laser damage threshold materials reported so far), so that constructive interference will lead to greater than 99% reflectivity of the incident intensity at the design wavelength. In our study, we constructed a design of mirror (HL)^11 H, with 23 alternate layers of zirconium and silicon oxide with quarter wave optical thickness which have peak reflectivity greater than 99% but in such design the peak standing wave electric field produced due to laser radiation lies on the first interface of high and low index materials, which is most prone to damage and, hence, the damage threshold of such design is low. In antireflective design above 99% transmission is achieved by 2HL by coating on both sides. By coating on single side about 97% transmission is achieved and by coating on both sides the required transmission is obtained. In this study design of high reflective and antireflective are made using ZrO_2/SiO_2 combination. These mirrors are formed by e-beam deposition method. Schematic diagram of deposition setup [6] is shown in the figure1.

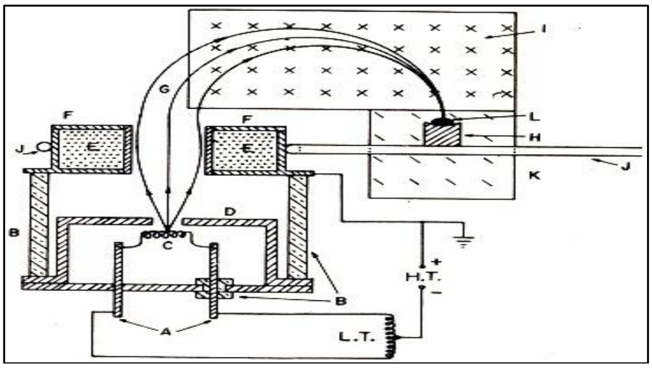

Fig 1: Schematic Diagram of Electron Beam Gun

Results and Discussion

Optical properties

High-reflective mirrors are desirable in many applications. These include high-finesse Fabry-Perot interferometers and low-loss laser resonators. Mirrors made of metallic films such as silver, aluminum or gold are generally of high reflection. For example, a silver mirror can achieve reflection approaching 99% in the visible spectrum. Approximately 1% of light energy penetrates the surface of the metal and gets absorbed in the bulk of the metal. These metallic mirrors cannot be used with high-power lasers because even a small fraction of absorption can cause severe heating problems. Thus there is a need to design high-reflection mirrors by using materials that have (almost) no absorption. The dielectric layered structure that consists of alternating quarter-wave layers of two different materials is the simplest way to obtain high reflection. This is the so-called Bragg reflector. If for a certain wavelength $\lambda 0$,the thicknesses d_1, d_2 and the refractive indices n_1 and n_2 of the consecutive layers can be controlled so that [7, 8].

$$n_1 d_1 = n_2 d_2 = \frac{\lambda_0}{4}$$

then the reflected beams from the different interfaces will all interfere constructively, leading to a peak in the reflection spectrum for this wavelength.

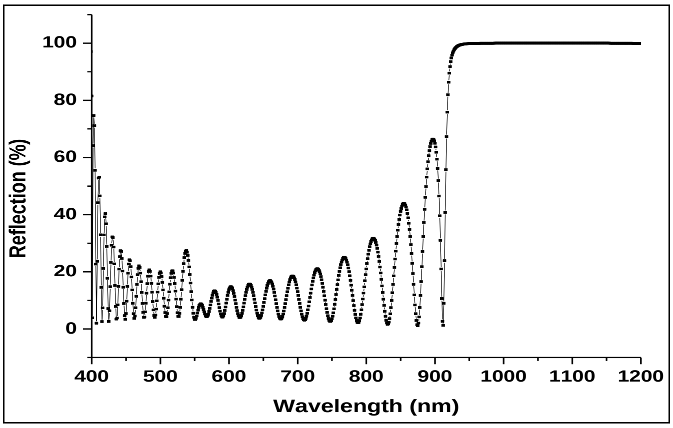

Fig 2: Reflection spectra of ZrO_2/SiO_2 multilayer stack

Reflection of the sample in IR region at 1064 nm is obtained more than the 99% as shown in the figure 2. At 350 nm its third harmonics also obtained with approximate same reflection value. In between these two peak reflectivity oscillating vibrations with low reflectivity is obtained as shown in the figure 2.

Minimal reflection or equivalently maximal transmission is desirable in many applications. One example is efficient coupling of light from a fiber into a waveguide. In designing an anti-reflective coating one needs to ensure that the reflection at the front of the coating interferes destructively with the reflection at the back of the coating [7, 8]. Assume a film thickness d. If $n_1 < n_2 < n_3$ with n_2 the refractive index of the coating, the two waves will interfere destructively if

$$d = \frac{1\lambda_0}{4n_2}$$

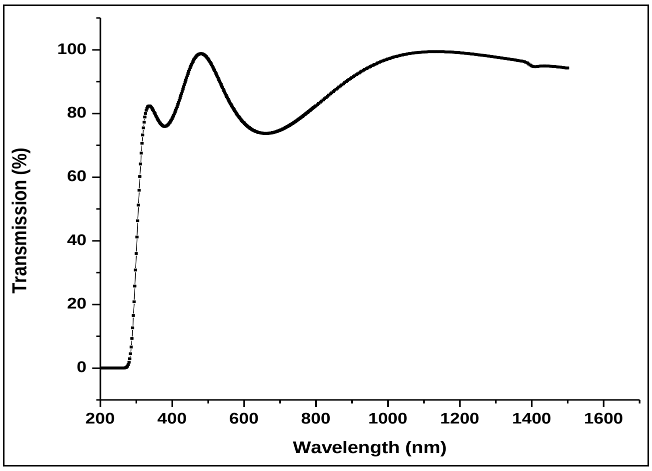

Fig 3: Transmission spectra of ZrO_2/SiO_2 multilayer stack

In the transmission spectra a broad peak from 1280 nm to 1028 nm of high transmission in IR region is shown in the figure 3. A decrease of transmission in visible region at wavelength 625 nm is notified below the 80% and then a sharp increase in transmission at 450 nm occurs as shown in the figure 3. As our design is formed for 99% transmission at 1064 nm in IR region so variation out-side this is meaningless.

Conclusions

The design of high reflective and antireflective coating is form for more than 99% reflectivity and transmission by using zirconium oxide and silicon oxide materials infrared region. The reflectivity of (HL)^11H is obtained 99.01%, where H stands for quarter wave optical thickness of high index material and L stands for quarter wave optical thickness of low index material. The refractive index of high index material is 2 and low index material is 1.46. Transmission of single side coating of design 2HL is more than 97% and for greater than 99% transmission both sides of the is required. Hence the required high reflective and antireflective coating are deposited.

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