Design and fabrication of anisotropic reflector with birefringent thin films for use at normal incidence

K M A Sobahan, Yong Jun Park and Chang Kwon Hwangbo

Department of Physics, Inha University, Incheon 402-751, Republic of Korea

asobahan@yahoo.com

Anisotropic reflectors with birefringent thin films have many potential applications for polarization-selective devices in laser optics. In this paper, a design and fabrication of anisotropic reflector with dielectric birefringent thin films for use with light at normal incident is presented. This reflector consists of a stack of quarter-wave dielectric birefringent thin films at design wavelength and it is performed on glass substrate with TiO_2 and SiO_2. These thin films are fabricated by oblique angle deposition technique. A dielectric thin film deposited obliquely behaves like an orthorhombic crystal and exhibits biaxial optical properties[1]. The parameters of an anisotropic layer can be controlled to some extent by altering the angle of deposition and the thickness of the coating material[2]. It has been suggested that anisotropic dielectric coating can be designed as an antireflection coatings, polarizers, retarders, etc. [3-4]. One period of the stack of the reflector is shown schematically in fig. 1.

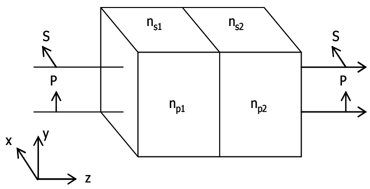

Fig.1. Refractive indices of the layers that form one period of the anisotropic reflector.

The values of refractive indices n_{p1}, n_{s1}, n_{p2}, and n_{s2} are determined by the anisotropic shapes and packing of the thin film columnar nanostructures and the *p* and *s* subscripts correspond to parallel and perpendicular to the deposition planes, respectively. In this case, the incident light polarized in the *p* sense will not produce any component *s* component of reflected and refracted light and vice versa, so that we can treat each of the polarizations separately, like as isotropic materials. Because the *p* and *s* polarizations propagate independently, standard results from the theory of isotropic multi-layers can be applied to the reflector. The principle of isotropic HR coating can be deduced from the Abelès matrix. Hence, the reflectance for *p* polarization light

$$R_p = \left[\frac{n_a - (n_{p1}/n_{p2})^{2N} (n_{p1}^2/n_g)}{n_a + (n_{p1}/n_{p2})^{2n} (n_{p1}^2/n_g)} \right]^2 \qquad (1)$$

and that for *s* polarization light

$$R_s = \left[\frac{n_a - (n_{s1}/n_{s2})^{2N}(n_{s1}^2/n_g)}{n_a + (n_{s1}/n_{s2})^{2n}(n_{s1}^2/n_g)} \right]^2 \qquad (2)$$

Where N is the number of periods in the stack and n_a and n_g are the refractive indices of incident medium and substrate, respectively. The design of the anisotropic reflector starts from the basic isotropic reflector design, aH(LH)g that can be extended to multiple periods, $aH(LH)^Ng$. Figure 2 and 3 show the simulated and experimental spectral reflectance of a TiO_2/ SiO_2 anisotropic reflector, and the associated values of the design parameters are $n_a = 1$, $n_g = 1.52$, $n_{s1} = 1.846$, $n_{p1} = 1.872$, $n_{s2} = 1.357$, $n_{p2} = 1.351$, N = 8 and design wavelength, $\lambda_0 = 633$ nm. The refractive indices, n_{s1} and n_{p1} are of TiO_2 thin film deposited at 30^o and that of n_{s2} and n_{p2} are of SiO_2 thin film deposited at 60^o. The anisotropy of TiO_2 film is 0.026 and that of SiO_2 film is 0.006.

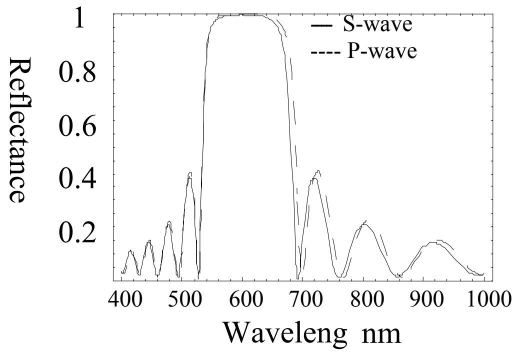

Fig. 2. Calculated spectral reflectance of a TiO_2/ SiO_2 anisotropic reflector. The design Parameters are $n_a = 1$, $n_g = 1.52$, $n_{s1} = 1.846$, $n_{p1} = 1.872$, $n_{s2} = 1.357$, $n_{p2} = 1.351$, $\lambda 0 = 633$ and N = 8

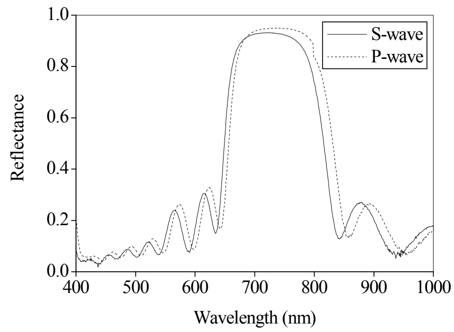

Fig. 3. Experimental spectral reflectance of a TiO_2/ SiO_2 anisotropic reflector.

The experimental results follow the simulation results except peak wavelength and reflectance amplitude. The experimental peak wavelength is higher and the reflectance amplitude is lower than that of simulation which may arise due to the higher thickness of the reflector during deposition and the absorption than that of simulation.

References

1. I. J. Hodgkinson and Q.H. Wu, Birefringent Thin Films and Polarizing Elements (World Scientific, Singapore, 1998).
2. I. J. Hodgkinson, Q. H. Wu and J. Hazel, Appl. Opt. 37, 2653 (1998)
3. A. Lakhtakia and M. McCall, Opt. Commun. 168, 457 (1999).
4. I. J. Hodgkinson and Q.H. Wu, Appl. Phys. Lett. 74, 1794 (1999).