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STUDY THE REFLECTANCE OF DIELECTRIC COATING FOR THE VISIBLESPECTRUM

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ABSTRACT

In this paper, study the reflectance of high-reflection (HR) coatings have been fulfilled by the use of the computer program MATLAB (version 7) using Sb_2S_3 and MgF2dielectric coating materialsas high (n=3) and low (n=1.38)refractive index materials respectively. The results show that the reflectance of the stack increases with increasing the number of layers in the stack.Also the results of effect of incidence angle shows that as the value of angle of incidence increase, the reflectance of S- polarization increase while the reflectance of P- polarization decreases, with shifting toward shorter wavelength of electromagnetic spectrum.

Keywords:- Reflectance, Dielectric Coating, Thin Film Interference.

1.INTRODUCTION

Multilayer optical thin film coatings have been extensively used for reflectivity modulation in various optical and optoelectronic components. These include anti- reflection (AR) and high-reflection (HR)coatings on laser diode facets, AR coating on lenses of camera and telescope, and fabrication ofpolarizing beam splitters and various optical filters [1].To further reduce the reflectance of AR coatings and to enhance the reflectance of HR coatings, multi-layer thin film coatings are employed. As we shall find, multi-layer coatings can be designed to possess broad spectral features as well. The reflectance of multilayer optical coating depends on the constructive or destructive interference of light reflected at successive boundaries of different layers of the multilayer stack[2].Anti-reflection coatings are designed so that the reflected light forms a destructive interference whereas the transmitted one forms a constructive interference. Destructive interference of the reflected light prevents the stray light in the system while the constructive interference increases the transmitted light intensity[3]. When the electromagnetic wave is incident on plane surface bonding two substances of indices n and $\bar{n}$ of the total radiation energy incident on an object, a fraction R is reflected from the top surface and a fraction T is transmitted through the bottom surface[4]. The remaining fraction is lost through electronic absorption (A) processes and by scattering (S) at surface and volume imperfections. Surface roughness, internal boundaries, and density fluctuations arising from porosity, pinholes, micro cracks, particulate incorporation, and impurities are sources of scattering. Adding the various contributions gives according to Equation (1) [5]. as shown in Figure 1 [6].

$$R + T + A + S = 1 \quad (1)$$

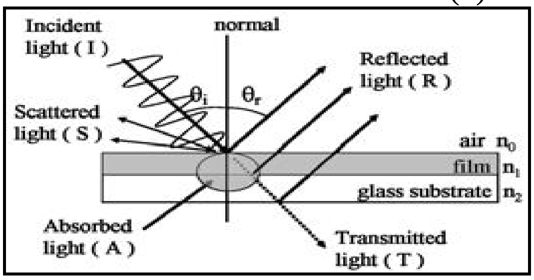

Figure 1. Incident beam divides into reflected, scattered, absorbed, and transmittedbeams[6].

The scattered and absorbed energies are generally very small compared with the transmittance and reflectance values, and for many applications these quantities can be ignored[7]. the dielectric coatings are superior to metal films in many respects. The all-dielectric-multilayer coatings can achieve high reflectivity with minimal scattering and absorption losses. In the absence of absorption and scattering losses at the interface between two media ,the relation:

$$R + T = 1 \quad (2)$$

must hold for reasons of energy conservation[2].The general concept of high-reflection (HR) coatings is usually based on the periodic layer system composed from two materials, one with a high index, such as zinc sulfide (n=2.35) or titanium dioxide (n=2.4) and low index material. This periodic system significantly enhances the reflectivity of the surface in the certain wavelength range. While the maximum reflectivity is increasing nearly up to 100% with a number of layers in thestack. High –reflecting coatings are used to produce mirrors used as output couplers in the world's most powerful lasers [8].A dielectric mirror consists of high and low refractive indices ,The optical thicknesses are typically chosen to be quarter-wavelength long, that is, $n_H l_H = n_L l_L = \lambda_0/4$ at some operating wavelength (λ_0)[9]. Mirror surfaces with very high reflectance can be produced using this arrangement [10,11]. In this work**,** we design high-reflection (HR) optical coatings in the visible region by the using computer program using Sb_2S_3 and MgF2dielectric coating materials as high (n=3) and low (n=1.38) refractive index materials respectively.

2. THEORETICAL BASIS

The multilayer optical coating usually consists of a stack of several layers of non-absorbing dielectric materials with different refractive indices[1]. Matrix calculations determine the spectral transmittance and reflectance profile for multilayer structures on a substrate[13]. Since the tangential components of E and H are continuous across a boundary, and since there is only a positive going wave in the substrate, the 2×2 matrix can be used to express the relationship which connects the tangential components of E and H at the incident interface with the tangential components of E and H which are transmitted through the final interface. This matrix is known as the characteristic matrix of the thin film[14].

$$\begin{bmatrix} E_b \\ H_b \end{bmatrix} = \begin{bmatrix} \cos\delta_2 & i\sin\delta_2/\eta_2 \\ i\eta_2\sin\delta_2 & \cos\delta_2 \end{bmatrix} \begin{bmatrix} E_c \\ H_c \end{bmatrix} \quad (3)$$

Where;

$$\delta = 2\pi N d \cos\theta / \lambda$$

$$\eta_s = Y N \cos\theta \quad \text{for S- Polarization}$$

$$\eta_r = \frac{Y N}{\cos\theta} \quad \text{for p- Polarization}$$

The input optical admittance of an assembly, Y, can be defined as:

$$Y = \frac{C}{B} = \frac{H}{E} \quad (4)$$

Equation (3) can be immediately extended to the general case of an assembly of *q* layers, when the characteristic matrix is simply the product of the individual matrices taken in the correct order, i.e.

$$\begin{bmatrix} B \\ C \end{bmatrix} = \left\{ \prod_{r=1}^{q} \begin{bmatrix} \cos\delta_r & i\sin\delta_r/\eta_r \\ i\eta_r\sin\delta_r & \cos\delta_r \end{bmatrix} \begin{bmatrix} 1 \\ \eta_m \end{bmatrix} \right\} \quad (5)$$

The reflectance is given by [14]:

$$R = \left(\frac{\eta_0 B - C}{\eta_0 B + C}\right)\left(\frac{\eta_0 B - C}{\eta_0 B + C}\right)^* \quad (6)$$

3. RESULTS AND DISCUSSION

We design a computer program using MATLAB version 7 to study and calculate reflectance for different materials (coatings) within visible spectrum. This program depends on refractive index of materials, number of layers and incident angle.Figure (2) show that the coating consists of Sb_2S_3 as high refraction index (n=3), MgF_2 as low refraction index (n=1.38) and the substrate (BK7) with the refractive index (n=1.52) for the central wavelength (λ_0=632.8 nm). The results are shown in Table 1.

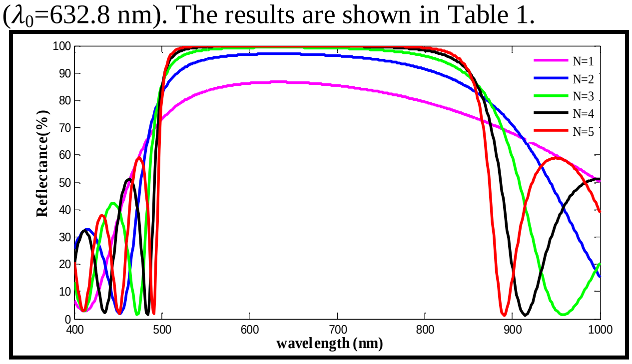

Figure 2: Reflectance as function of wavelength for Air/H $(LH)^N$/Bk7 for normal incident atλ_o=632.8 nm, where $n(Sb_2S_3)$=3, n(MgF2)=1.38 and n(BK7)=1.52

Table 1: Values of reflectance for Sb_2S_3, MgF2 coating on the substrate (BK7)for normal incident

No.	Design	Reflectance (%)
1	Air /H $(LH)^1$/Bk7	87.25
2	Air /H $(LH)^2$/Bk7	97.16
3	Air /H $(LH)^3$/Bk7	99.39
4	Air /H $(LH)^4$/Bk7	99.87
5	Air /H $(LH)^5$/Bk7	99.97
6	Air /H $(LH)^6$/Bk7	99.99
7	Air /H $(LH)^7$/Bk7	100

It is clear that the magnitude of the reflectance increases with the number of layers. The number of side band oscillations outside the high-reflectance zone also increases with number of layers. The high-reflectance central zone increases with increasing values of the index ratio nH/nL, it is used to obtain high reflectance value with the least number of layers**.**To obtain a high reflectivity by reducing the number of layers, one can use incident angle as a variable, as the incident angle increases, the admittance of TE polarization increases and that of TM polarization decreases. So the reflection bandwidth of TE polarization is wider than that at normal incidence, and that of TM polarization is narrower. Therefore, at a high incident angle and reference wavelength, the reflectance of TM-polarized light may be quite low in contrast to the high reflectance of TE-polarized light [5]. The results are shown in Table 2.

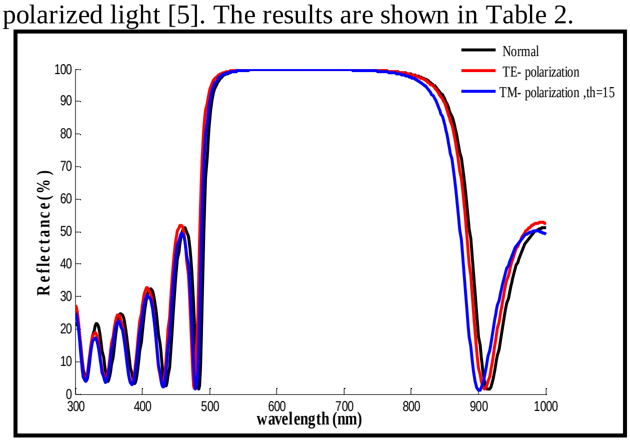

Figure 3: Reflectance as function of wavelength for Air/H $(LH)^4$/Bk7 at λ_o=632.8 nm,θ = 15° where $n(Sb_2S_3)$=3, n(MgF2)=1.38 and n(BK7)=1.52

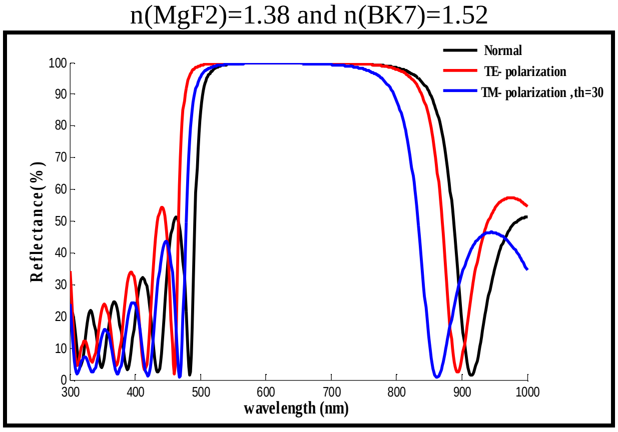

Figure 4: Reflectance as function of wavelength for Air/H $(LH)^4$/Bk7 at λ_o=632.8 nm, θ = 30° where $n(Sb_2S_3)$=3, n(MgF2)=1.38 and n(BK7)=1.52

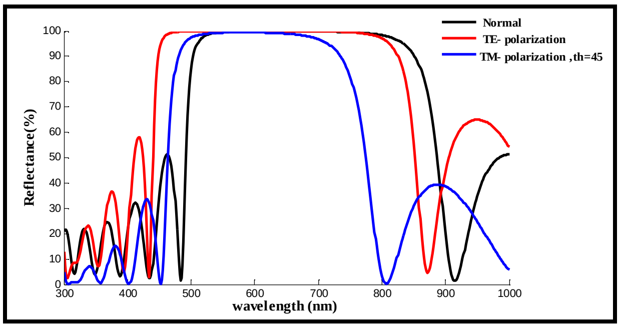

Figure 5: Reflectance as function of wavelength for Air/H $(LH)^4$/Bk7 at λ_o=632.8 nm, θ = 45° where n(Sb_2S_3)=3, n(MgF2)=1.38 and n(BK7)=1.52

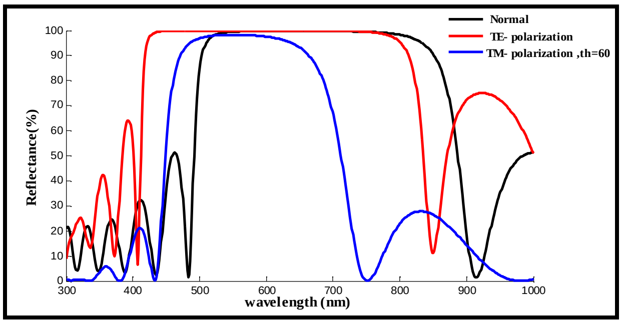

Figure 6: Reflectance as function of wavelength for Air/H $(LH)^4$/Bk7 at λ_o=632.8 nm, θ = 60° where n(Sb_2S_3)=3, n(MgF2)=1.38 and n(BK7)=1.52

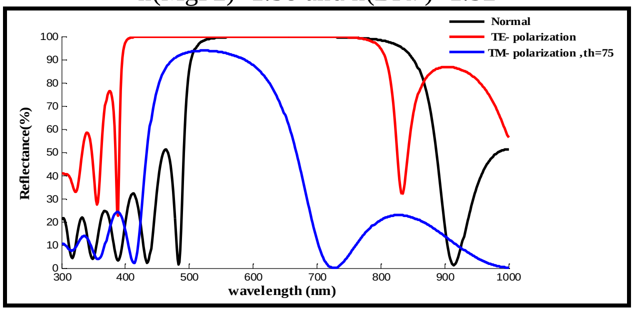

Figure 7: Reflectance as function of wavelength for Air/H $(LH)^4$/Bk7 at λ_o=632.8 nm, θ = 75° where n(Sb_2S_3)=3, n(MgF2)=1.38 and n(BK7)=1.52

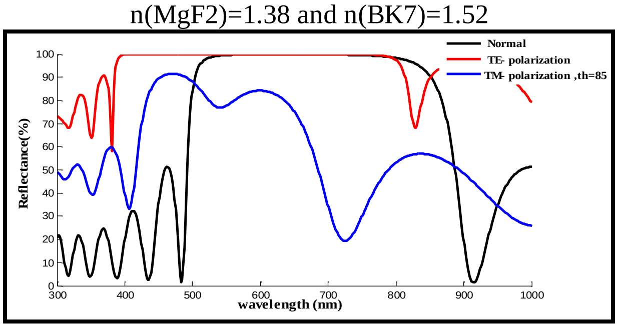

Figure 8: Reflectance as function of wavelength for Air/H $(LH)^4$/Bk7 at λ_o=632.8 nm, θ = 85° where n(Sb_2S_3)=3, n(MgF2)=1.38 and n(BK7)=1.52

In general, the effect of increasing the incident angle is the reflectance of S- polarization increase while the reflectance of P- polarization decreases, witha shift in the whole reflectance curve towardshorter wavelengths .This kind of behavior is evidenced by several naturally occurring periodic structures.

Table 2: Values ofreflectance for Sb_2S_3, MgF2 coating on the substrate (BK7) for oblique incident

Number of figure	Incidence angle	Reflectance (%)	Wavelength (nm)
4	0°	99.86	(610.8 - 657)
4	15°	R_{TE}>99.87	(594 –662.6)
		R_{TM}>99.83	(599.6 - 655.6)
5	30°	R_{TE}>99.92	(575.8 – 643)
		R_{TM}>99.74	(591.2 – 624.8)
6	45°	R_{TE}>99.96	(629 – 542.2)
		R_{TM}>99.43	(571.6 - 591.2)
7	60°	R_{TE}>99.98	(494.6 – 630.4)
		R_{TM}>98.3	(543.6 - 560.4)
8	75°	R_{TE}>99.99	(454 - 643)
		R_{TM}>93.81	(518.4 - 529.6)
9	85°	R_{TE}=100	(444.2- 644.4)
		R_{TM}>91.43	(466.6 – 473.6)

Now we are study the effect ofchange in substrate material on the reflectivity of the design air/$(HL)^N$H/substrate at the normal incidence. The results are shown in table 3and table 4.we achieve that the maximum reflectance at used Bk-7 as a substrate compared with LaSF9 and ZnSe.

Table 3: Reflectanceas a function ofchange substrate material.

Design No.	Design	Reflectance %
1	Air/((Sb_2S_3/$MgF_2)^2$/ Sb_2S_3/BK7	97.02
2	Air/(Sb_2S_3/$MgF_2)^2$/ Sb_2S_3/LaSF9	96.39
3	Air/(Sb_2S_3/$MgF_2)^2$/ Sb_2S_3/ZnSe	94.98

Table 4: Reflectance as a function of change substrate material.

Design No.	Design	Reflectance %
1	Air/((Sb_2S_3/$MgF_2)^4$/ Sb_2S_3/BK7	99.86
2	Air/(Sb_2S_3/$MgF_2)^4$/ Sb_2S_3/LaSF9	99.84
3	Air/(Sb_2S_3/$MgF_2)^4$/ Sb_2S_3/ZnSe	99.77

4.CONCLUSION

From above results can be concluding that,at the design wavelength (λ_o), the reflectance has a maximum value, depending on number of layers in addition to angle of incidence. The addition of layers does not affect the width of the zone of high reflectance, but increases the reflectance within it and the number of oscillations outside. The width of the zone is a function only of the indices of the two materials used in the construction of the multilayer the higher the ratio is the greater the width of the zone.we achieve that maximum reflectance at used Bk-7 as a substrate compared with LaSF9 and ZnSe.It appears that the best substrate was Bk7.

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