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SYNTHESIS OF NON-POLARIZED SHORT-WAVE PASS FILTERS FOR THREE REGIONS

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ABSTRACT

Novel construction stacks were proposed to design the non-polarization short-wave pass edge filters for three regions. By using appropriate materials systems with adjusting their film thickness, we could to overcome the problem of polarization separation and got superior optical performance of non-polarized short-wave pass filter at the incident angle 45^o. The creative designs were characterized by the high transmittance reached to 100% with limited improving the performance in passband and completely intersecting of the S and P- polarization.

Keywords: non-polarized filters, edge filter.

1. INTRODUCTION

The basic property of edge filters is an abrupt change between a region of rejection (stopband), and a region of transmission (passband), the high transmittance in the passband is usually desired [1, 2, 3]. Thin-film edge filters as long-wave passes or short-wave passes are often essential components of an optical device. A typical application of such an edge filter is the optical arrangement used for fluorescence microscopy. Also these filters are widely used in wavelength division multiplexers (WDM), and optical fibre communication systems (fibre sensors), [4, 5, 6].

The demand of non-polarized edge filters in such applications necessitated the efficiently investigation for a new designs. At oblique incident where light reaches to surface at angle bigger than (0^o), it will be polarized owing to the angle effect. The polarization is expressed in term of two modes, S-polarization and P-polarization [7, 8]. S and P transmittances will be different because of changing of refractive indices and phase thickness where they are sensitive to any change in the angle of incidence. Also the increase of incidence angle expands the separation of S and P- polarization waves with shifting toward shorter wavelengths [7]. In most optical techniques the loss of information through polarization effect is not an acceptable [9, 10]. So it is necessary to avoid this and S and P-components need to be reflected or moved with minimal separation at all [10].

The design of non-polarized edge filter for applications is a very difficult and interesting challenge. This paper proposes a new and promising materials system to build a non-polarized short wave pass filter for different three regions, these new construction stacks of non-polarized short-wave pass filter are designed with just using high and low refractive index materials.

2. THEORETICAL PRINCIPLES

Coatings at oblique incidence other than normal cause special problems. First there is the shift in properties with angle of incidence that follows roughly a cosine law. At higher angles of incidence the cosine curve becomes very steep implying a much more rapid variation in properties with angle of incidence than there is near normal incidence [11].

In this case the optical performance of the two polarizing modes is different so it is important to be considered. For that we should to modify the refractive indices of each coating layer. The modified refractive indices are represented bythe following [6, 7]:

n_S $= n^* \cos\theta$
The effective refractive index for s-polarization
n_P $= n/\cos\theta$

The effective refractive index for p-polarization

where
n is normal refractive index of coating layer
θ is a refraction angle of light in coating layer

To complete the representation of optical performance with greater accuracy we must calculate the effective index for surroundings media .The incident and exit media have refractive indices n_o and n_{sub}, respectively.

The modified effective refractive index of incident medium is clarified by [7]:

$\eta_o =$ $n_o^* \cos\theta_o$
for s-polarization
$\eta_o =$ $n_o/\cos\theta_o$
for p-polarization
where (θ_o)is incident angle
η_o is effective refractive index of incident medium

The effective index of exit medium (substrate) is clarified by:

$\eta_{sub} =$ $n_{sub}^*\cos\theta_s$
for s-polarization
$\eta_{sub} =$ $n_{sub}/\cos\theta_s$
for p-polarization
where θ_s is a refraction angle of light in substrate.
η_{sub} is the effective refractive index of substrate.

This study depend characteristics matrix to determine the spectral transmittance profile for multilayer structures on a substrate. The matrices of each individual coating layer where they refer by Ms and Mp for S and P polarization are given as following [6]:

For s-polarization

$$\begin{bmatrix} \cos\delta_s & (i\sin\delta_s)/n_s \\ in_s\sin\delta_s & \cos\delta_s \end{bmatrix}$$

For p-polarization

$$\begin{bmatrix} \cos\delta_p & (i\sin\delta_p)/n_p \\ in_p\sin\delta_p & \cos\delta_p \end{bmatrix}$$

Depending on what previously mentioned characteristic matrix for the multilayer thin films can be represented as [6]:

$$\begin{bmatrix} B \\ C \end{bmatrix} = M\begin{bmatrix} 1 \\ \eta_{sub} \end{bmatrix}$$

Where M is the multiplying of the individual matrices for all coating layers taken in arranging. Consequently M is compensated by the product of Ms matrices for S-polarization and Mp matrices for P-polarization.

$\begin{bmatrix} B \\ C \end{bmatrix}$ is defined as the characteristic matrix of the assembly.

Using the matrix relationship that is given above and Fresnel's law yields transmittance T as follows [3, 12]:

$$T = \frac{4\,\eta_o(\eta_{sub})}{(\eta_o B + C)(\eta_o B - C)^*}$$

3. MATERIALS CONFIGURATION AND DESIGNS DISCUSSION

Materials can be used to design reasonable non-polarizing coatings at only certainangles, whereas other materials can be made to serve for other angles. The choice of materials seems to be critical to the success of any particular requirement. Since the range ofpractical coating materials and substrates is limited for most applications [9, 11].

In this work we used new promising materials systems in design. These materials systems provided high optical performance of non-polarized short-wave pass filters and we were able to overcome the design problems at incidence angle of 45 °. The designs reporting that non-polarization short-wave pass filters at incidence angle of 45 ° have been designed within three different regions.

a) Visible region

This section includes presenting of new construction design stack of short-wave pass filter for visible region (0.45-0.8μm). The result showed optimal optical performance of short-wave pass filter by utilizing of new materials system in design.

This design stack consisting of Sb_2S_3 as high refractive index material (n=3.2), and (MgF_2) as low refractive index material (n=1.38) with adopting glass as a substrate. Using appropriate materials with adjusting their film thickness, we could to get superior optical performance of non-polarized short-wave pass filter.

From Figure-1 we can see that the transmittance curves of s-polarized and p-polarized light are intersected and relatively have the same performance. The design provided stopband from (0.65 to 0.8 μm). However the stopband of s-polarized and p-polarized light are not separated under 45° oblique incidence. Passband is from (0.45 to 0.65 μm) and it is characterized by high transmittance reached to 100% with reducing ripples in transmittance band.

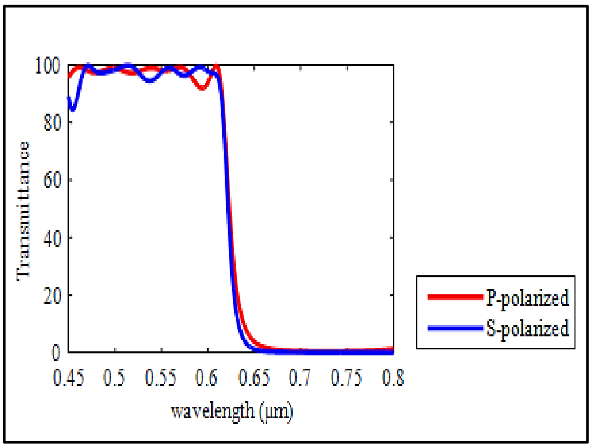

Figure-1. Optical performance of non-polarized short-wave pass filter for visible region with construction design stack: 0.1721H 0.6536L 0.1721H 0.9375L 0.2174H 0.8080L 0.2174H 0.9375L 0.7506H 0.5413L 0.4799H 0.5413L 0.7506H 0.6306L 0.9138H 0.1948 0.9138H 0.6309L 0.6309H 0.9138L 0.1948H 0.9138L 0.6309H 0.6309L 0.9138H0.1948L 0.9138H 0.6309L 0.6309H 0.9138L 0.1948H 0.9138L 0.6309H 0.7506L 0.5413H 0.4799L 0.5413H 0.7506L 0.9391H 0.2174L 0.8080H 0.2174L 0.9375H 0.2822L 0.4037H 0.2822L

b) NIR region

a new reasonable coating materials were configured to get another new design stack of non-polarized short-wave pass filter for near infrared region (NIR) (1-1.8 μm) under 45° oblique incidence. Materials system consisting of ZnS as high refractive index material (n=2.98) and (MgF_2) as a low refractive index material (n=1.38) with adopting glass as a substrate.

It is obvious from Figure-2 that the stopband and passband extended along (0.4 μm) where the splitting performance is not degraded. The two planes of polarization is still intersected and got high transmittance with small ripples.

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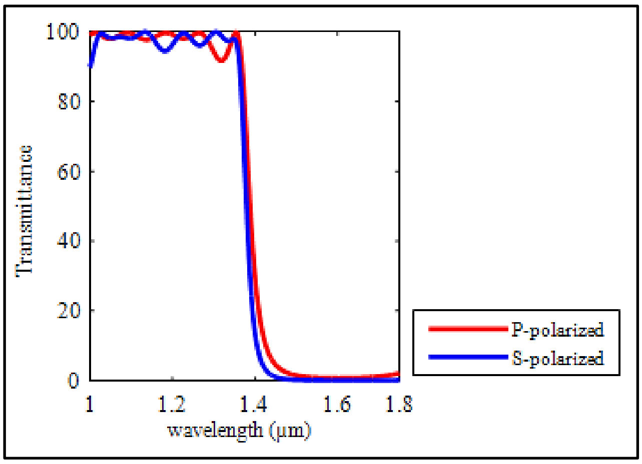

Figure-2. Optical performance of non-polarized short-wave pass filter for NIR region with construction design stack: 0.1727H 0.6536L 0.1728H 0.9412L 0.2174H 0.8112L 0.2174H 0.9412L 0.7535H 0.5413L 0.4818H 0.5413L 0.7535H 0.6331L 0.9138H 0.1956L 0.9138H 0.6334L 0.6334H 0.9138L 0.1956H 0.9138L 0.6334H 0.6334L 0.9138H 0.1956L 0.9138H 0.6334L 0.6334H 0.9138L 0.1956H 0.9138L 0.6334H 0.7535L 0.5413H 0.4818L 0.5413H 0.7535L 0.9412H 0.2174L 0.8112H 0.2174L 0.9412H 0.2833L 0.4037H 0.2833L

c) MIR region

Short-wave pass filter was constructed with using different materials system for mid wave infrared region (MIR) (3-5.5 μm) under 45° oblique incidence.
The construction design stack is composed of Si as high refractive index material (n=3.42) and SiO as a low refractive index material (n=1.6) with adopting Silicon monoxide as a substrate.

Figure-3 is shown a good performance of short-wave pass filter, where there is no splitting between the performance of s-polarization and p-polarization light. The design is characterized by the wide stop band with completely intersecting of the polarization planes. The passband is from (3-4.5) with limited improving the performance in transmittance band.

4. CONCLUSIONS

Multilayer thin films has sensitivity under oblique incident the optical performance curves of the s-polarization and p-polarization light in conventional short-wave pass filter will separate clearly at 45° oblique incidence.

Based on using promising creative materials systems, a new stack structure of short-wave pass filter is designed for three regions. From results it's obvious that we overcame the problem of polarization separation and got optimal performance of short-wave pass filter. Where there is no splitting in performance of s-polarization and p-polarization light and improving the performance in transmittance band by reducing ripples.

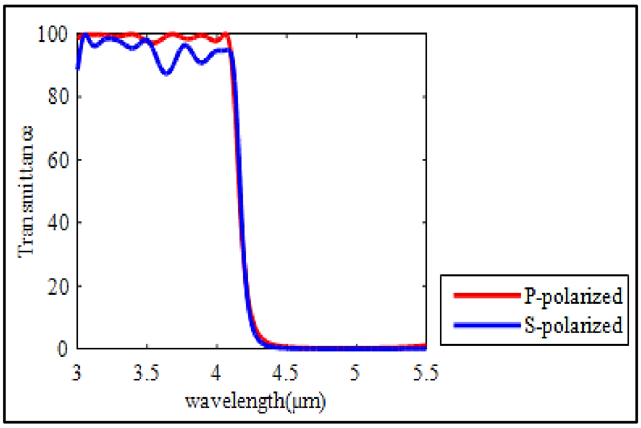

Figure-3. optical performance of non-polarized short-wave pass filter for MIR region with construction design stack: 0.1715H 0.6257L 0.1715H 0.9345L 0.2081H 0.8054L 0.2081H 0.9345L 0.7482H 0.5181L 0.4783H0.5181L 0.7482H 0.6286L 0.1942H 0.8748L 0.8748H 0.6289L 0.6289H 0.8748L 0.1942H 0.8748L 0.6289H 0.6289L 0.8748H 0.1942L 0.8748H 0.6289L 0.6289H 0.8748L 0.1942H 0.8748L 0.6289H 0.7482L 0.5181H 0.4783L 0.5181H 0.7482L 0.9345H 0.2081L 0.8054H 0.2081L 0.9345H0.2813L 0.3865H 0.2813L

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