Effects of Thin Film Multi Layers Thickness and Refractive Index on Narrowband Filters Transmission's

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الخلاصة

أن تأثير معامل الانكسار وسمك الغشاء في تطبيقات الطلاء متعددة الطبقات مهم جدا للحصول على العرض الضيق للنبضة. خلال التبخير، يمثل اختيار معامل الانكسار، اختياراً لمواد الطلاء، والتي يجب أن تكون متوافقة مع مادة القاعدة، بالإضافة إلى أن دقة سمك طبقات الطلاء تؤدي دورا مهماً في نوعية الطلاء متعددة الطبقات والسيطرة على العمليات والتحكم في التكلفة والتي يمكن قياسها بطرق مختلفة.

في هذا البحث، قمنا بدراسة تصميمية وتحليلية نظرية لنوع من المرشحات المساة بمرشحات تمرير الحزم. أن اختيار المواد وأختلاف عدد طبقات التصاميم الغرض منه هو الحصول على عرض نبضة ضيق أقل ما يمكن. التصميم الاول TiO2/SiO2، التصميم الثاني inGaAs/SiO2 والتصميم الثالث GaAs/SiO2 كلاً من هذه التصاميم تتكون من (31) طبقة وتم عرضها على التوالي. وتتكون هذه التصاميم من اثنين من المواد ذات معاملات الانكسار عالي/ واطئ ضمن نطاق الطول الموجي (750-1100) نانومتر، والطول الموجي للتصميم (900) نانومتر.

تظهر النتائج تأثير سمك الطبقات ومعامل الانكسار على منحني النفوذية والطول الموجي لجميع تصاميم متعدد الطبقات العازلة. ومن خلال النتائج التي حصلنا عليها عرضنا أفضل تصميم لهذا النوع من المرشحات للحصول على نبضات الليزر الضيقة.

الكلمات المفتاحية

مرشحات تمرير الحزم، GaAs/SiO2، TiO2/SiO2، نبضات الليزر الضيقة

Abstract

Both thickness and refractive index of a multi-layered membrane have a great effect on getting a narrow pulse width. So choosing the coating material should be regarded with accuracy of refractive index. The thickness of multilayer of coating has an important effect on type of multilayered coating material and at the end has a great role on cost control.

In this paper we will get analysis and design of different kinds of filters named band-pass filter, by choosing materials for different coating to have less possible narrow pulse width. The 1st design is TiO2/SiO2, 2nd design In GaAs/SiO2 and 3rd design is GaAs/SiO2, each of these designs consists of a number of layers (31) are presented respectively. These designs consist of two materials high/low index with wavelength range from (750-1100) nm and the design wavelength is (900) nm.

From this study we get the effect of thickness and refractive index by having the transmission characteristics curve versus wavelength for any type of dielectrics thin film of multilayered membrane. At the end we get optimal design for a narrow laser pulse width.

Keywords

Band-pass filter, TiO2/SiO2, InGaAs/SiO2 , GaAs/SiO2, Narrow laser pulse width

1. Introduction

Optical elements consist of surfaces which have the ability to control and adjust the light passing through it. Optical devices associated with the performance of these surfaces run effectively on reflection and absorption of light according to the desired application and percentages calculated in practice and light to determine the percentage of cases of reflection, absorption and transmission depending on the coating layers and the type of material used.

Depending on the Fabry Perot principle, we can discuss the basic design of the can at an arrow package of optical interference. This type of interference belongs to the category known as the standards of the multiple beams overlap, because there is a very large amount of radiations which are participating in the interference [1].This scientific device Fabry and A. Perot in 1899 was designed to study the phenomenon of interference between multiple beams of light. Our high quality interference band passen filters passing narrow bandwidth light and reflecting every other light. In principle interference filters can be designed and manufactured to almost any specification of centre wavelength and band pass [2].

The standard ranges of stock filter are available from the range (214-2000) nm in many bandwidths from narrow 3nm FIN type up to (65-100) nm FIW type to meet various requirements [2]. The difference between the two lies in the fact that the design of Fabry Pero thus a flat surface that reflects search part. So multiple light rays are responsible for creating the observed interference patterns [3]. The device was shown in Fig. 1. Interior faces reflect an increase (95%), both of which reflected waves then falling multiple reflections and parallel, so that, the mirror can be controlled to change the distance between them.

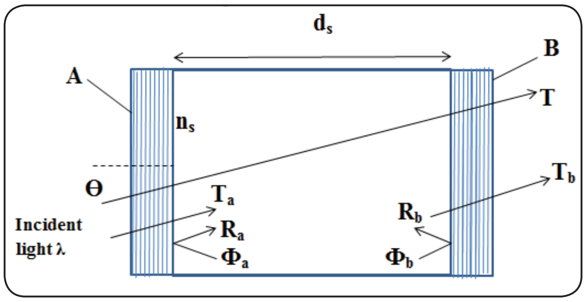

Fig. (1): Structure of a Fabry-Perot interferometer [2].

Fig. (1) shows the scheme Fabry Peru over lapin the form of graph. Fabry Peru design consists of two plates act as mirrors (A,B) of parallel reflective surfaces separated by (ds). Low transmission for all wavelengths except a series of very narrow band›s transmission [4], in which the half of the central wavelengths are equal to integer number times of the spacer›s optical thickness [4].

Where:

n_s : the refractive index of the material,

d_s : the physical thickness of the spacer,

Θ : the incident angle of the collimated light,

λ : the wavelength of the collimated light,

ϕ_a and ϕ_b : are the phase change of the light on the reflecting surface and .

T_a and T_b : are the transmittances of the reflecting surface and , and

R_a and R_b : are the reflectance of the reflecting surface and .

The amplitude reflection and transmission coefficients are defined as shown below. Basic theory of the multiple-beam interferometers shows that the transmittance of the plane wave is given by [1]:

$$T = T_{\max} \cdot \left[\frac{1}{1 + F \sin^2\left(\frac{1}{2}(\phi_a + \phi_b) - \delta\right)} \right] \quad \ldots (1)$$

Where [2]: $T_{\max} = \frac{T_a T_b}{[1-(R_a R_b)^{1/2}]^2}$

$$F = \frac{4(R_a R_b)^{1/2}}{[1-(R_a R_b)^{1/2}]^2} \quad , \delta = \frac{2\pi}{\lambda} n_s d_s \cos\theta$$

Equation (1) propounds some information from Fabry-Perot interferometer.

Band pass Filters Mathematical Analyses

Perut device is a representation of the simpler design of the narrow band pass filter, it can take the form of the following equation |reflector |spacer |reflector|. And alternating layers as high/low index stack will be high reflectance at the design wavelength. There has been a form of Fig.(1). The maxima transmission happened when it is at the central wavelength . The relationship is as follows:

$$\phi = \frac{2\pi}{\lambda_p} n_s d_s \cos\theta - \frac{\phi_a + \phi_b}{2} = m\pi, \ \ldots(2)$$

$$m = 0, \pm1, \pm2, \pm3, \ldots.$$

So, the central wavelengths are given by [1]:

$$\frac{1}{\lambda_p} = \frac{1}{2 n_s d_s \cos\theta}\left(m + \frac{\phi_a + \phi_b}{2\pi}\right) \ \ldots(3)$$

If $\phi_a = \phi_b = 0$, meaning that the central wavelength of the filter is only dependent on the optical thickness of the spacer layer and the angle of incident. When changing the angle of incident, the central wavelength of the filter will therefore be shifted to the short wave side of the central wavelength [4].If the bands be sufficiently narrow, with F being sufficiently large enough, so near a peak we can replace [4]:

$$\sin^2\left(\frac{1}{2}(\phi_a + \phi_b) - \delta\right) \text{ by: } (\Delta\delta)^2 \ldots(4)$$

We can calculate half width by noting that at the half-peak transmission points [4]:

$$\frac{1}{2} = \frac{1}{1 + F\sin^2\left(\frac{1}{2}(\phi_a + \phi_b) - \delta\right)} \approx \frac{1}{1 + F(\Delta\delta)^2} \ \ldots(5)$$

So, we get the half width of the pass band $2\Delta\delta = \frac{2}{\sqrt{F}}$ or:

$$\Delta\lambda_h = \frac{2\Delta\delta}{m\pi}\lambda_p = \frac{2}{m\pi\sqrt{F}}\lambda_p \ \ldots(6)$$

if case the reflecting surfaces are symmetric, we have $R_a = R_b = R_s$.

So, $\Delta\lambda_h = \frac{(1-R_s)}{m\pi\sqrt{R_s}}\lambda_p$.

From the above equation, we can reduce the half width of the pass band, and we can use high order of m (increase the thickness of the spacer) or increase the reflectance of the reflecting surfaces. If the reflectances and transmittances of the two surfaces are equal, and let them be R_s and T_s, then the maximum transmittance can be written as: $T_{\max} = \frac{T_s^2}{[1-R_s]^2}$.When absorption is neglected in the reflecting coating, the maximum transmittance should be equal to 1. However, if the absorption $A = 1 - T_s - R_s$, the maximum transmittance should be written as follows:

$$T_{\max} = \frac{T_s^2}{[1-R_s]^2} = \frac{T_s^2}{[1-(1-T_s-A)]^2} = \frac{1}{\left(1+\frac{A}{T_s}\right)^2} \ \ldots(7)$$

Therefore, the absorption will decrease the maximum transmittance of the filter. Besides, if the reflectance›s and transmittances of the two surfaces are unequal and the absorptions are negligible, the maximum transmittance of the filter can be written as follows:

$$T_{\max} = \frac{T_a T_b}{[1-(R_a R_b)^{1/2}]^2} = \frac{T^2(T_s + \Delta)}{[1-(R_s(R_s - \Delta))^{1/2}]^2}$$

$$= \frac{T_s(T_s+\Delta)}{\left(1-R_s\left[1-\frac{1}{2}\left(\frac{\Delta}{R_s}\right)+........\right]\right)^2} \cdots(8)$$

Where: $R_a = R_b - \Delta = R_s - \Delta$,
$T_a = T_b + \Delta = T_s + \Delta, \Delta \langle\ R_s$ and $R_s + T_s = 1$.

So, when the reflectance of the two surfaces are unequal, the maximum transmittance of the filter will decrease:

$$\approx \frac{T_s^2}{(1-R_s)^2}\frac{1+\frac{\Delta}{T_s}}{\left[1+\frac{1}{2}(\frac{\Delta}{T_s})\right]^2} \approx (1+\frac{\Delta}{T_s})(1-\frac{\Delta}{T_s}) \approx 1-(\frac{\Delta}{T_s})^2 \langle 1 \cdots(9)$$

Simulation Result and Discussion

In general, the narrow band-pass filters consists of two parts:

1. The actual design of the narrow band-pass characteristic (transition from low to high transmittance band, a high transmittance band, and the transition from high to low transmittance).
2. This type of blocking filters which provide a rejection in wavelength regions, where due to their periodic nature, the narrow band-pass designs have high transmittance zones.

Transmission curve of these types of filters consists of a very sharp peak at the design wavelength. For most applications, the shape was undesirable. Instead, there is a more rectangular shape required with the high transmission zone extending over a range of wavelengths. A narrow band-pass filter has high transmittance in the narrow wavelength region (λ_1 to λ_2) and high rejection (low transmittance high reflectance) in all other wavelength regions ($\lambda \rangle \lambda_1$ and $\lambda \rangle \lambda_2$). And the structure of the most common multi-cavity band-pass filters (narrow band-pass filters) is a filter made up of all the dielectric and consisting of a quarter-wave optical thick layers for the mirrors and a half wave optical thick, or multiple half wave optical thick layers of spacers [5].

In this work we will limit ourselves to the narrow band-passes actual design. Table (1) shows layers thickness as a function of layers materials for 1st designTiO2/SiO2as high/low/high index (n_H=2.230 and n_L= 1.460).

Table (1): Layer structure of 1st design narrow band pass filter.

No.	Materials	Thicknesses (nm)	No.	Materials	Thicknesses (nm)
1	TiO_2	100.597	17	TiO_2	100.597
2	SiO_2	153.156	18	SiO_2	153.156
3	TiO_2	100.597	19	TiO_2	100.597
4	SiO_2	153.156	20	SiO_2	153.156
5	TiO_2	100.597	21	TiO_2	100.597
6	SiO_2	153.156	22	SiO_2	153.156
7	TiO_2	100.597	23	TiO_2	100.597
8	SiO_2	612.625	24	SiO_2	612.625
9	TiO_2	100.597	25	TiO_2	100.597
10	SiO_2	153.156	26	SiO_2	153.156
11	TiO_2	100.597	27	TiO_2	100.597
12	SiO_2	153.156	28	SiO_2	153.156
13	TiO_2	100.597	29	TiO_2	100.597
14	SiO_2	153.156	30	SiO_2	153.156
15	TiO_2	100.597	31	TiO_2	100.597
16	SiO_2	153.156			

While, Table (2) and Table (3) show the constructions parameters for the 2nd design In GaAs/SiO2/InGaAs (n_H=3.68 and n_L= 1.46) and 3rd design GaAs/SiO2/GaAs (n_H=3.59 and n_L= 1.46) respectively.

Table (2): Layer structure of 2nd design narrow band-pass filter.

No.	Materials	Thicknesses (nm)	No.	Materials	Thicknesses (nm)
1	InGaAs	61.034	17	InGaAs	61.034
2	SiO_2	153.156	18	SiO_2	153.156
3	InGaAs	61.034	19	InGaAs	61.034
4	SiO_2	153.156	20	SiO_2	153.156
5	InGaAs	61.034	21	InGaAs	61.034
6	SiO_2	153.156	22	SiO_2	153.156
7	InGaAs	61.034	23	InGaAs	61.034
8	SiO_2	612.625	24	SiO_2	612.625
9	InGaAs	61.034	25	InGaAs	61.034
10	SiO_2	153.156	26	SiO_2	153.156
11	InGaAs	61.034	27	InGaAs	61.034
12	SiO_2	153.156	28	SiO_2	153.156
13	InGaAs	61.034	29	InGaAs	61.034
14	SiO_2	153.156	30	SiO_2	153.156
15	InGaAs	61.034	31	InGaAs	61.034
16	SiO_2	153.156			

Table (3): Layer structure of 3rd design narrow band-pass filter.

No.	Materials	Thicknesses (nm)	No.	Materials	Thicknesses (nm)
1	GaAs	62.608	17	GaAs	62.608
2	SiO_2	153.156	18	SiO_2	153.156
3	GaAs	62.608	19	GaAs	62.608
4	SiO_2	153.156	20	SiO_2	153.156
5	GaAs	62.608	21	GaAs	62.608
6	SiO_2	153.156	22	SiO_2	153.156
7	GaAs	62.608	23	GaAs	62.608
8	SiO_2	612.625	24	SiO_2	612.625
9	GaAs	62.608	25	GaAs	62.608
10	SiO_2	153.156	26	SiO_2	153.156
11	GaAs	62.608	27	GaAs	62.608
12	SiO_2	153.156	28	SiO_2	153.156
13	GaAs	62.608	29	GaAs	62.608
14	SiO_2	153.156	30	SiO_2	153.156
15	GaAs	62.608	31	GaAs	62.608
16	SiO_2	153.156			

Characteristic of the transmission curve for the 1st, 2nd and 3rd design are shown in Fig. (2), Fig. (3) and Fig. (4).

The refractive indices of 1st, 2nd and 3rd design are varied, so the desired optical profile of the assembly is obtained. The layers are replaced with stacks of high and low index materials.

Conclusion

This research studied the theory of design and analysis of the band-pass filter. We conclude the fact that:

1. The refractive index and thickness of the membrane in multi-layered coating applications is very important to get a narrow laser pulse width.
2. Choosing the refractive index means choosing a coating material, which must be compatible with the base material that is through evaporation.
3. The effects of layers thickness and the refractive index on the transmission characteristics curve versus wavelength for each dielectric thin film multilayer›s designs.

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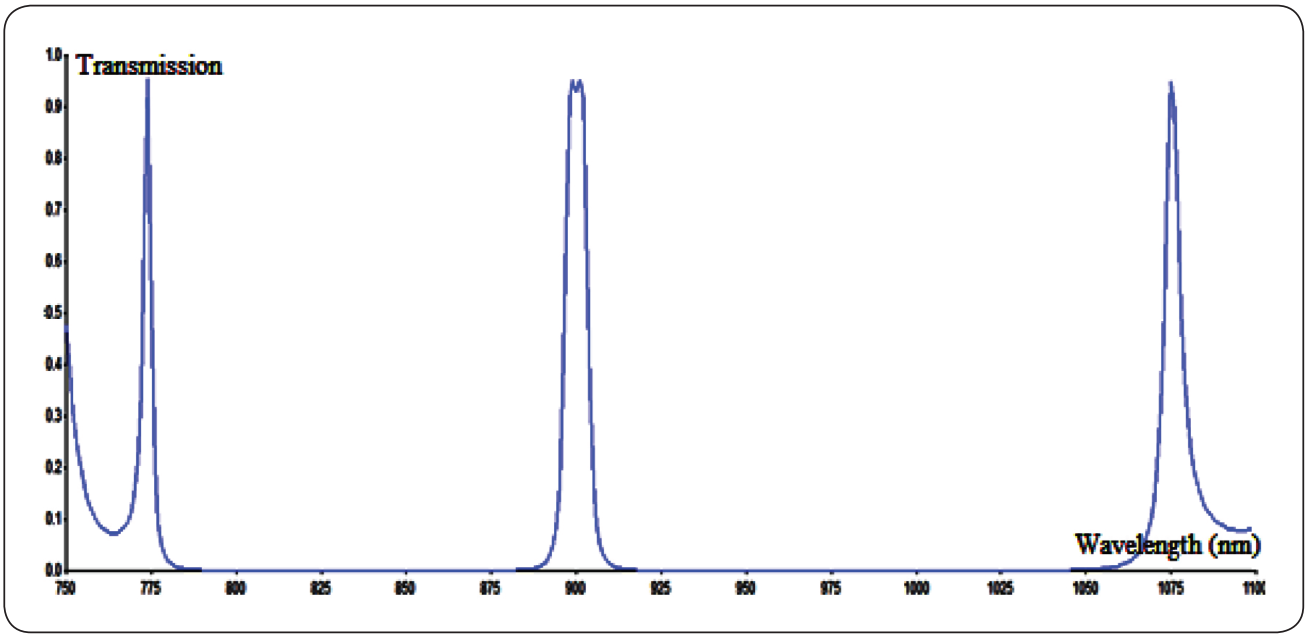

Fig. (2): Transmittance vs. wavelength for 1st design (TiO2/SiO2/TiO2) band-pass filter is used for as high/low index (n_H= 2.230) and (n_L= 1.460), with wavelength range from (750-1100) nm and the design wavelength (900) nm.

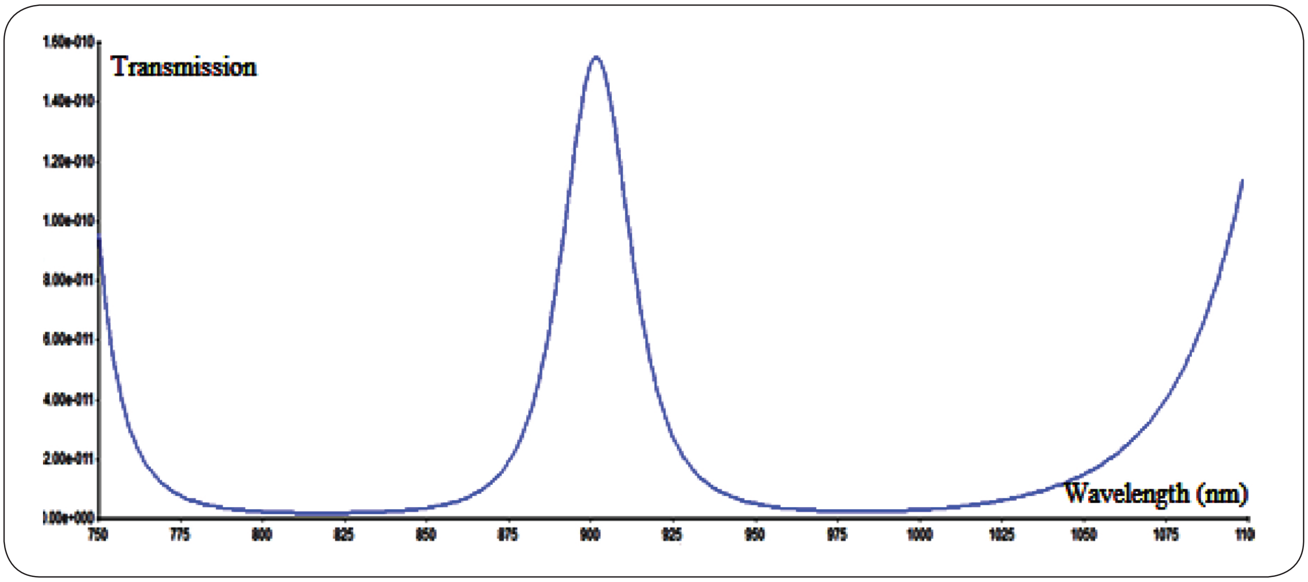

Fig. (3): Transmittance vs. wavelength for 2nd design (InGaAs/SiO2/InGaAs) band-pass filter is used for as high/low/high index (n_H= 3.68 and n_L= 1.46), with wavelength range from (750-1100) nm and the design wavelength (900) nm.

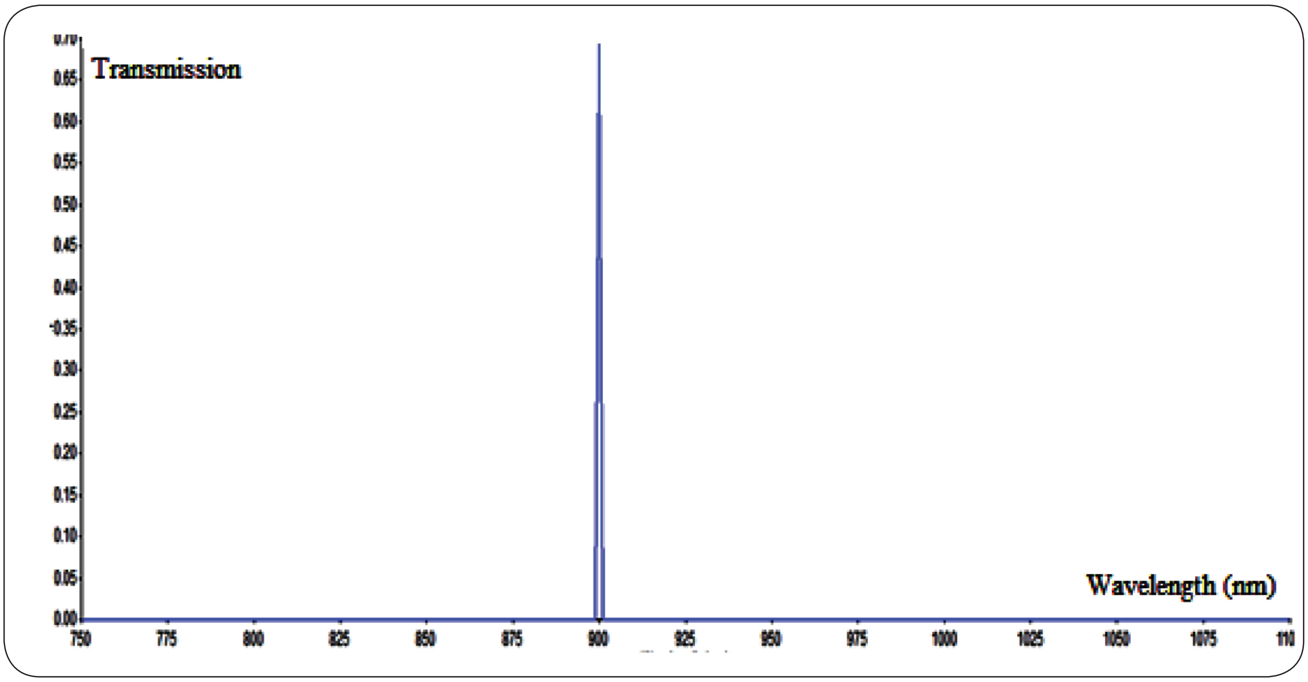

Fig. (4): Transmittance vs. wavelength for 3rd design (GaAs/SiO2) band-pass filter is used for as high/low/high index (nH= 3.59 and nL= 1.46), with wavelength range from (750-1100) nm and the design wavelength (900) nm.