Design of Layered Optical Filters in Infrared Bands Using Different Materials

FUG

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Introduction

- In this Project duty is designing a new photonic crystal which reflect, transmit or absorb electromagnetic waves.
- Photonic crystal-based multilayer structures can be used in fields such as defense industry, energy, optics applications, biomedicine, microwave resonators.
- Biosensors are used to detect various biological targets. For example, biosensors can be used to detect bacteria, viruses and cancer cells.
- It was decided to design a new biosensor as a project work.

Specifications and Design Requirements

- Central wavelength: $\lambda_0 = 550\ nm$
- General Sequence:

$$Air/(SiO_2/Te/S\,iO_2)^N/D/(SiO_2/Te/S\,iO_2)^N/glass$$

- The second cell (LHL) of the Fibonacci series was used while creating the general sequence.
- The defect layer consists of water and waterborne bacteria.

Materials	Refractive Index	Thickness
SiO_2	1.45	$d_{SiO_2} = \frac{\lambda_0}{4n_{SiO_2}}$
Te	4.234	$d_{Te} = \frac{\lambda_0}{4n_{Te}}$
Defect	-	$d_{SiO_2} + d_{Te}$
$Glass$	1.5	-

Table 1 Materials and Specifications

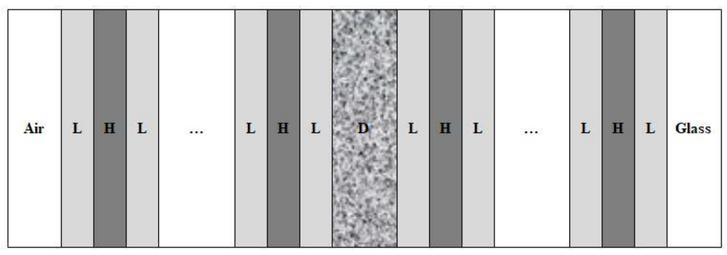


Figure 1 The layout of the designed multilayer structure

Solution Methodology

- The **Transfer Matrix Method** was used in the analysis of this study.
- The Transfer Matrix Method is a method used to analyze the propagation of optical and acoustic waves in a multilayered medium.

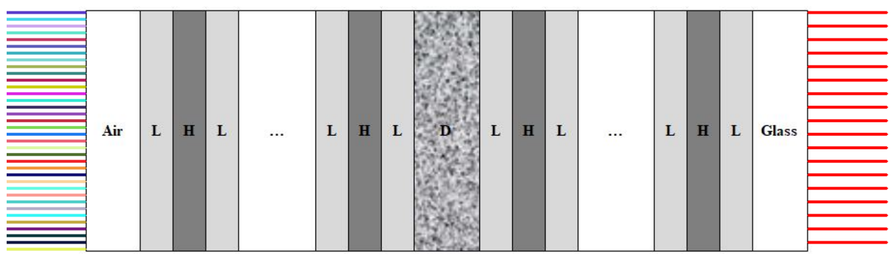


Figure 2 Propagation of Light in a Multilayer Structure

- With the Transfer Matrix Method, the transmission, reflection and absorption power ratio of the structure is calculated.

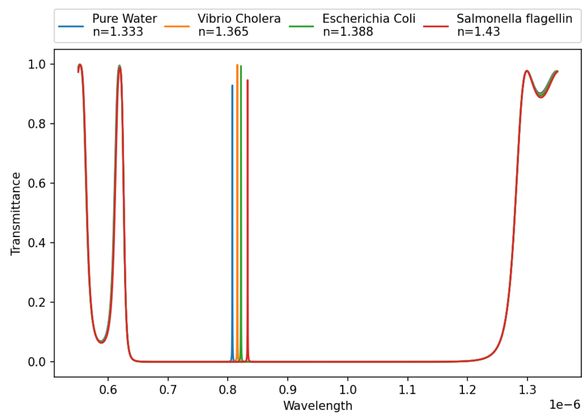
$$M = M_0(M_AM_BM_A)^N M_D(M_AM_BM_A)^N M_S = \begin{bmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{bmatrix} \quad (1)$$

$$M_m = \frac{1}{\tau}\begin{bmatrix} e^{j\phi_m} & \rho_{m-1}e^{-j\phi_m} \\ \rho_{m-1}e^{j\phi_m} & e^{-j\phi_m} \end{bmatrix} \quad (2)$$

- Photonic crystal analysis was done in **PYTHON** and **MATLAB**. For this, our own algorithm has been developed.

Results and Discussion

By using the second cell of the Fibonacci series, a wide stopping band gap was obtained. When the medium containing water-borne bacteria is added as a defect layer to the photonic crystal structure, a transmitted power peak occurs. It has been shown that the presence and density of bacteria can be determined by looking at the amount of shift.



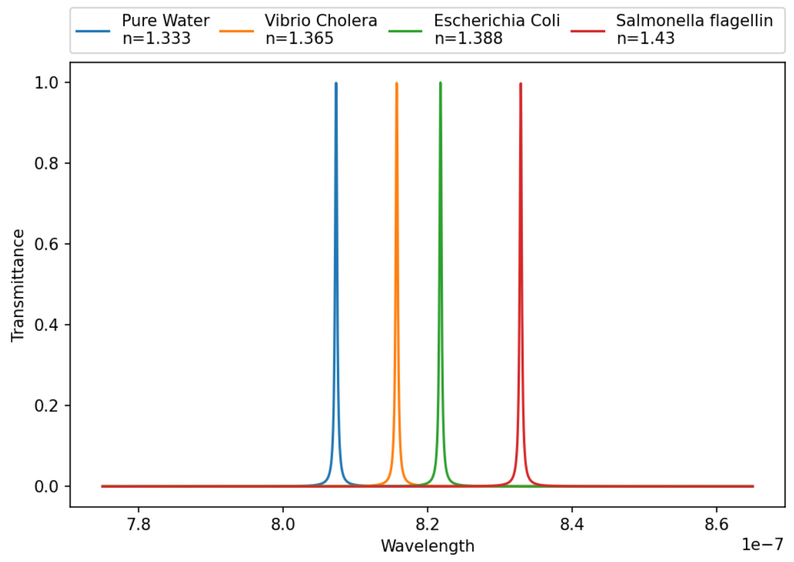


Figure 3 Transmittance Characteristics of Designed Biosensor

- The detection mechanism of the biosensor we have designed is based on the difference in refractive index between pure water and bacterial samples carried by water.
- The designed sensor structure is thinner or has higher contrast when compared to similar structures in the literature.

Publications and Conference Participation

- Furkan Çözeli, Umut Uğurlu ve Çiğdem Seçkin Gürel, **Fibonacci Serileri ile Bakteri Tespiti Amaçlı Fotonik Kristal Biyosensör Tasarımı**, İstanbul Yeni Yüzyıl University, 8th Science Days Congress, 9-11 May 2022, page: 88.

References

- S.A. Taya, D.N. Alhamss, I. Colak, S.K. Patel (2022) Sensitivity enhancement of an optical sensor based on a binary photonic crystal for the detection of Escherichia coli by controlling the central wavelength and the angle of incidence
- S.Khaleel & Ç.S. Gürel (2012) A new narrowband multilayer DWDM optical filter in the order of defected Fibonacci sequence, Journal of Electromagnetic Wave and Applications, 26:14-15, 1930-1938
- A. Panda, P.D. Pukhrambam (2021) Investigation of defect based 1D photonic crystal structure for real-time detection of waterborne bacteria

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