Research Article

Realization of Sensing Applications in Nanophotonic Waveguide using Sugar, Salt and Alcohol Solutions

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A B S T R A C T

In broad sense, a waveguide is a device which constrains of guide the propagation of an electromagnetic waves along a path defined by the physical construction of the guide. Basically waveguide is medium, which present in between transmitter and receiver, i.e. it a medium where data can be transmitted from transmitter end to reciver end. Now day's different types of waveguide are being used for the sake transformation of data for purposes. Out of these nanophononic waveguide is one of them.

Keywords: Nanophotonic, Sugar Solution, PBG

Introduction

Nanophotonic waveguide is special type of waveguide, where a quantum of single mode of electromagnetic field is distributed in the waveguide.[1-4] Normally, light energy is transmitted from transmitter end to receiver end through nanophotonic waveguide. The amount of light energy transmits from transmitter end to nanophotonicwave guide will not reach the same amount of light energy at the receiver end. This is due to loss of energy in the waveguide. This loss in waveguide is due to the absorption and reflection light energy by that waveguide. Then, rest amount of light will be reached at the receiver end. To maximize the transmitted light energy or maximize the efficiency of waveguide, one has to minimize the loss of energy in the same. Now days the minimization of loss of energy in the waveguide is big challenge for us.[5] To solve this challenge, people from different fields, physics, electronics, electrical and computer are applying different techniques for fabricating the waveguide, which will give high efficiency. Beside this, the size of waveguide plays vital role for minimizing the energy loss. Looking these aspects, we have designed a new type of nanophotonic waveguide, called as photonic crystal waveguide, which can be fitted in a planer light wavecircuits the interesting is that this waveguide absorbs almost zero amount of light energy during the transmission through it. Then to find out the maximum transmitted light energy, we have optimized its reflectance. Basically, light through photonic crystalwaveguide is based on the principle of photonic bandgap.

In this paper, we have organized as follows: In section 1, concepts of photonic crystal with different solutions are presented. In section 2, importance of sugar, salt and alcohol solution is discussed. In section 3, mathematical descriptions are made. In section 4, simulation results and discussions are shown.

ICSSCI-2019: International Conference on Recent Advances in
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Mishra CS et al.
J. Engr. Desg. Anal. 2020; 3(2)

Photonic Crystal Structure with Different Solutions

Photonic crystals are novel materials, composed of periodic dielectric structures that affect the electromagnetic waves.[6] The dielectric structures depend on the periodic function of permittivity of the materials, which differs from different directions. Taking the above concept, one can construct 1D, 2D and 3D photonic crystals. Electromagnetic wave at a particular range of frequencies cannot propagate though the crystal, which is called photonic band gap. This is an analogue of electronic semiconductor where the crystalline atomic lattices act on the electron wave function to produce electronic band gap.[7,8] Interestingly the photonic band gap changes with the dimension and dielectric constant of the repeating units. For example in a 2D photonic crystal, (realized by drilling a number of air holes on glass plate), it is found that the photonic band gap of particular materials can be changed by changing the dimensions of air holes and spacing. Further if the dielectric constant of air hole region is changed by introducing some other materials, the Photonic Band Gap (PBG) also changes. As the transmitted intensity from such structure depends on the PBG, one can relate dielectric constant with PBG of that structure. We use this principle to measure the change in intensities of transmitted light by introducing certain solution's like sugar aqueous solution, common salt aqueous solution and alcohol (1-Popanol) aqueous solution in the air hole regions.

The photonic crystal which we have considered for measuring the energy of transmittance is a square type 2D- photonic crystal and shown in Figure 1.
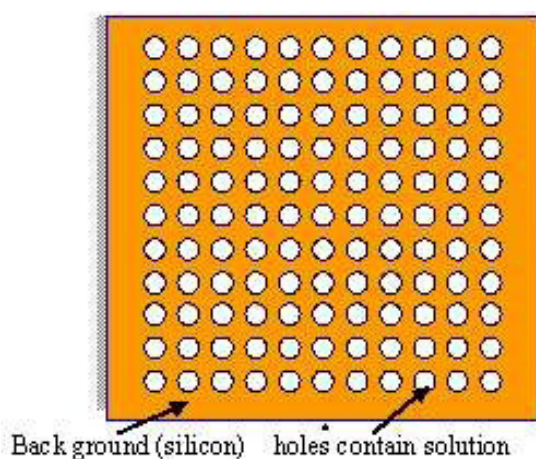

Figure 1.Square lattice 2D photonic crystal having holes radius 0.4 μm and separation between two holes is 1 μm

It consists of air holes of radius 0.4μmand lattice constant is 1μm. The photonic band gap of material changes by changing the dielectric constant of air holes (ea), background (eb) or both. Apart from this the same can be changed by changing the radius of air holes, lattice spacing or both.

Importance of Sugar, Saltand Alcohol Solution

The uses of sugar, salt and alcohol solutions play important role in our society.[9,10,11] Depending on the concentration ofsugar, salt and alcohol in aqueous solution, we can use this solution for different purposes.[12,13] Basically, these solutions are important in the field of medical science i.e. for clinical applications, such as sugar solution is used for hypoglycemia and saline etc., salt solution used for burns or injuries, throat infection, allergies etc. and alcohol solution is used for anesthesia and antisafetic.[14,15] The following sub sections give brief description of the importance of sugar, salat and alcohol solution.

Importance of Sugar Solution

Now a day's dehydrations and diarrhea are the common diseases in world. Basically Oral Rehydration Therapy (ORT) is a simple treatment for dehydration associated with diarrhea, particularly gastroenteritis or gastroenteropathy, such as that caused by cholera or rotavirus.[16] ORT consists of a solution of salts and sugars that is taken by mouth. It is used around the world, but is most important in the developing world, where it saves millions of children a year from death due to diarrhea, the second leading cause of death (after pneumonia) in children under five.[17] Where ORS sachets are not available, home-prepared solutions are typically used. While many different recipes exist to increase palatability, all are based on a standard ratio of water, sugar, and salt. A basic oral rehydration therapy solution is composedof:

- 30 ml (6 level tsp) of sugar
- 2.5 ml (1/2 level tsp) of salt, dissolvedinto
- 1 litre (4.25 Cups) of cleanwater

The concentration of sugar, salt in ORS should be taken proper amount.

Beside this, another type of serious disease, called diabetics, is seen in the world.[18] This disease occurs due to the increase of sugar level in blood, i.e. More than the normal level in the blood. If sugar level in the blood decreases, i.e. bellow than normal level then another type of serious disease occurs called a hypoglycemia.[19] Hypoglycemia is the state of having a blood glucose (also known as blood sugar) level that is too low to effectively fuel the body's cells.[20]

Glucose is a sugar thats's derived from the breakdown of carbohydrates found in foods, and the main source of fuel for the body (including the brain).[21] It may be stored in the liver andmuscles for later use, but excess glucose is converted to fat. The level of glucose in the blood is regulated by complex hormonal and neurologic mechanisms. The normal range of blood glucose throughout the day and night is approximately 70 to 150 mg/dl (milligrams of glucose per deciliter of blood).[22] However, this varies according to a number of factors; your child's doctor will talk with talk

*ICSSCI-2019: International Conference on Recent Advances in
Computer Science, Soft Computing and Information Technology*

*Mishra CS et al.
J. Engr. Desg. Anal. 2020; 3(2)*

with you about what should be a normal range for him. The brain depends on glucose, and too little can impair its ability to function. Severe or prolonged hypoglycemia could result in seizures and serious brain injury.[23] The vast majority of episodes of hypoglycemia in children and adolescents occur when a child with diabetes takes too much insulin and/or eats too little or exercises strenuously or for a prolonged period of time. For young childrenwho do not have diabetes, hypoglycemia may be caused by:

- Stomach flu or another illness that may cause them to not eat enough
- Fasting for a prolonged period of time
- Prolonged strenuous exercise and lack of food

Treatment: Healthy babies are fed as soon as possible after birth. Treatment for infants with hypoglycemia may include:

- Oral glucose solution
- Oal feedings of breast milk or formula
- IV infusions of a glucose solution
- Other medications

Importance of Salt Solution

Although salt solutions are being applied in all fields such as aquaculture, agricultural but clinical applications of salt solution play important role. The following are discussed for the same.

Sore Throat: The simplest remedy for minor sore throat pain is a warm saltwater gargle. Just add 1 teaspoon salt to 8 ounces warm water and gargle several times a day. See a physician if the sore throat persists longer than 3 days or isaccompanied by a high fever.[24]

Burns or Injuries: A severe burn in your mouth from eating something very hot can be relieved by rinsing with saltwater every hour or so. Use 1/2 teaspoon salt in 8 ounces warm water.[25]

Gums: Swish with 1 teaspoon salt in 4 ounces warm water when gums are painful. If you have an abscess, the salt will draw out some of the infection. Any gum pain should be treated by a dentist as soon aspossible.[26]

Bee stings and bug bites: Work a mixture of salt and water into a paste that will stick to a bee sting or bug bite. Apply the paste and let sit until dry. This should relieve any itch or pain.[27]

Allergies: Irrigating the nostrils and sinuses with saltwater is an excellent way to control persistent, annoying allergy symptoms.[28] Dissolve 1/2 teaspoon salt in 8 ounces room temperature water. Draw Mixture Into Nose Dropper and in hale liquid through your nostrils. Repeat several times for each nostril, using 2 or 3 drops of the solution each time. When you are through, blow your nose until no discharge remains.

Eye Treatments

A diluted solution of 1/2 tsp. of sea salt to a pint of water can be used to wash and relieve tired eyes. Use the same solution with hot water to dab around eyes to reduce puffiness.[29]

Apart from these, salt solution is also used for Injection; USP is a sterile, nonpyrogenic solution for fluid and electrolyte replenishment in single dose containers for intravenous administration. It contains no antimicrobial agents.[30]

Also salt solution is used in aquaculture, such as parasite control, osmoregulatory stabilization, mucus production, and alleviation of methemoglobinemia in freshwater fish.[30] Salt concentration is based on intended use, duration of exposure and tolerance of the species to be treated.[31]

Importance of Alcohol Solution

Alcohols have applications in industry and science as reagents or solvents.[32] Because of its low toxicity and ability to dissolve non-polar substances, ethanol can be used as a solvent in medical drugs, perfumes, and vegetable essences such as vanilla. In organic synthesis, alcohols serve as versatile intermediates. Apart from this, alcohol plays vital role in the field of medical science.[33]

Alcohol is an important industrial ingredient and has widespread use as a base chemical for other organic compounds. These include ethyl halides, ethyl esters, diethyl ether, acetic acid, ethyl amines, and to a lesser extent butadiene.[34]

Alcohol is also used in medical wipes and in most common antibacterial hand sanitizer gels at a concentration of about 62% v/v as an antiseptic.[35] It kills organisms by denaturing their proteins and dissolving their lipids and is effective against most bacteria and fungi, and many viruses, but is ineffective against bacterial spores.[36]

Apart from this, alcohol is miscible with water and is a good general purpose solvent.[37] It is found in paints, tinctures, markers, and personal care products such as perfumes and deodorants. It may also be used as a solvent or solute in cooking, such as in vodka sauce.[38]

Alcohol was commonly used as fuel in early bipropellant rocket (liquid propelled) vehicles, in conjunction with an oxidizer such as liquid oxygen. The German V-2 rocket of World War II, credited with beginning the space age, used ethanol, mixed with 25% of water to reduce the combustion chamber temperature.[39,40] The V-2's design team helped develop U.S. rockets following World War II, including the ethanol-fueled Redstone rocket, which launched the first U.S. satellite. Alcohols fell into general disuse as more efficient rocket fuels were developed.

As far as animal diseases are concerned, alcohol injection of Morton's neuroma has a high success rate and is well

ICSSCI-2019: International Conference on Recent Advances in Computer Science, Soft Computing and Information Technology

Mishra CS et al.
J. Engr. Desg. Anal. 2020; 3(2)

tolerated. The results are at least comparable to surgery, but alcohol injectionis associated with less morbidity and surgical management may be reserved for non responders. This alcohol solution is also used for cleaning of pets (cats, dog etc.) ear. [41]

Methodology

There are different methods to compute the photonic band gap of photonic crystal like FDTD[46,11] (finite difference time domain), PWE (plane wave expansion)[47,12] TMM (Transfer matrix method).[48,13] But we choose PWE method to compute the photonic band gap. The reason for opting PWE is due to high accuracy.[49,14] One of the main demerits of this method is its limitation to treat losses as the differential operator in Helmholtz equation is not Hermitian in lossy medium. But in sensing application, these demerits can be avoided. FDTD through can be used but gives spurious solution, which appears during the response spectrum analysis, hence is not suitable for our investigation.

When one investigate the light propagation in 2 D photonic crystal along Z axis and radiation has TE, polarization (Non zero Hz, Ex, Ey), the Maxwell's equation can be written as

$$\frac{\partial}{\partial x}E_y - \frac{\partial}{\partial y}E_x = -\frac{1}{c}\frac{\partial}{\partial t}B_z \qquad (1)$$

$$\frac{\partial}{\partial y}H_z = \frac{1}{c}\frac{\partial}{\partial t}D_x \qquad (2)$$

$$-\frac{\partial}{\partial x}H_z = \frac{1}{c}\frac{\partial}{\partial t}D_y \qquad (3)$$

Using above equations, Helmoltz equations for such a radiation filed can be obtained.

The wave functions are represented in terms of Bloch waves and expanded in to Fourier's series over the lattice vectors. Inversed dielectric constant is also expanded in to Fourier series. Substituting this in equation (5.4), the eigen value for Fourier expansion coefficient are obtained as

Where $G_{||}$ and $G'_{||}$ are in plane reciprocal lattice vector.

$K_{||}$ is in plane vector and $\omega^{(e)}_{K_{||},n}$ is the frequency of TM mode.

$\chi(G_{||})$ for dielectric rods can be expressed as

$$\chi(G_{||}) = 2f(\frac{1}{\in_1} - \frac{1}{\in_2})\frac{J_1(G_{r||})}{G_{r||}}$$

Where $J_1(G_{r||})$ is the first order of nessel's function. For simulation we compute the photonic band gap using Equation (6) and limit thevariation of Brillioun zone $\frac{-\pi}{T} \cdots \frac{\pi}{T}$ G and G' within

$\frac{-2\pi N}{T} \cdots \frac{2\pi N}{T}$ Where (2N+1) is the number of

plane waves taken into account Using equation 6, we write down the matrix differential operator for each values of wave vector within the selected range and the Eigen states of obtained matrix is computed.

Result and discussion

In this case, sodium light having wavelength 589 nm is allowed to incident on photonic crystal. Then photonic crystal reflects some amount of light energy, which is called photonic band gap. Since the thickness of materials is an extremely small, the transmitted energy is only depends on the photonic band gap. So transmitted energy is equal to incident energy minus photonic band gap.

For the simulation of band gap of 2D photonic crystal structure , we have chosen structure parameter properly, which is shown in Table 1.

Table 1.2D photonic crystal structure parameters

2D photonic crystal	
Back ground material	Silicon (Si)
Permittivity of Silicon	11.7
Lattice constant (a)	1 μm
Radius of air holes	0.6 μm

Conclusion

We use sodium light source of wavelength 589 nm to incident on 2Dphotonic crystal structure filled with the alcohol solution in air holes enclosed by two glass slides firmly .The transmittance power (intensity) is measured by photo detector. The variation of transmitted light is reaching the detector with the changes of concentrations of alcohol can be measured. For Figure 1 we have shown this for alcohol solution, which suggests that the concentration of alcohol solution can be directly computed from the transmittance value.

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ICSSCI-2019: International Conference on Recent Advances in Computer Science, Soft Computing and Information Technology

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J. Engr. Desg. Anal. 2020; 3(2)

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