Design A Sensor Mach Zender Interferometer for the Detection of Chemical and Organic Substances Present In Food and Health Drinks

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Abstract: This Paper includes the nano cavity implementation of the biosensors in the detection of any chemical analyte and pesticide. Chemical, organic substances or any biological analytes are deemed to be present in any food or soft drink. Detection of these kinds of analytes are the potential risk. Photonic Crystals are rapid and precise to reach the sky for the next future. The photonic crystal model simulation is performed using Beam Propagation technology, with change in the refractive index in one selected arm. Therefore the designed MZI acts as a bio sensing device to detect any kind of chemical, bio analyte and organic substances that are present in different food. MZI has many advantages in photonic crystal with the use of least instrument and ready to be compatible with CMOS technology. The experimental program is observed for minute change in refractive index, in this work. Mach Zender Interferometer shall behave as sensor for small change in refractive index of pesticide value and observed power and intensity thus will be accounted. Indicates that it is highly sensitive for the changes in refractive index and in turn it can differentiate between normal food which do not contain any chemical and pesticide present in food.

Keywords: Mach Zender Interferometer using beam prop; Nanocavity-coupled waveguide; photonic crystal; Rsoft.

I. INTRODUCTION

Pests, organic chemicals and unwanted plants will be damaged by the pesticide which is basically a chemical compound. It can be used in public health to spoil different kind of disease, such as mosquitoes. For human body Pesticides are potentially toxic [1]. In soft drinks, bottled water, and food, pesticides are found. Each drink was tested for common insecticides including 16 organ chlorine pesticides, 12 organ phosphorus pesticides.

Centre of safety excellence experimented and observed high level of toxic pesticide and that causes the high level cancer and damage to lever, nervous system and making very low immune system. The drink and carbonated beverage Section Committee, FAD 14, of the Bureau of Indian Standards has been ruminated on the issues of pesticide which is present in the soft drink.

There are different kinds of sensor that can be constructed using photonic crystal to detect the pesticide but MZI which is containing some best features and easy to maintain and fabricate as sensor. Based on the MZ interferometer, MZI receives optical continuous wave and that will be splitted into two branches and each contains its phase shifter. With good sensitivity MZI is used to detect the pesticide chemicals. MZI is proposed with arms, among them one is used for sensitive purpose and other one is used for reference purpose. Therefore micro ring resonator structure may not be used in photonic crystal which is cost effective for POC (point of care) application. In order to achieve the low detection limit, the addition of high precision fabrication technique is required to obtain the high quality device. Compared to micro ring resonator sensors, MZI sensor is easy to design [2]. MZI based sensor can be demonstrated by using different types of material such as silicon oxides. Silicoonoxynitride, silicon nitride silicon-on-insulator (SOI), and even polymers.

II. THEORY

Core and cladding are the basic arrangement of Optical integrated circuits. Some features of optical integrated circuit are i) single-mode optical wave propagation [3], ii) Easy to control the waveguide. iii) Short interaction length and low operating voltage. iv) Optical power density is large. iv) in order to measure the phase shift between the two beams if there is a change in length of one of the path of the interferometer and that has been used among other things [4]. There are many applications such as aerodynamics, plasma physics and heat transfer and temperature design, this kind of designed sensor can be used. The basic feasibility is the light can be easily controlled in the reference channel without disturbing the light in the object which makes the Mach Zender configuration channel popularized in holographic interferometer. In order to form higher-index guiding layers on substrates and that is possible by deposition, thermal in diffusion, ion exchange, epitaxial growth [5]. For fabrication of 3-D waveguides micro fabrication techniques, including photolithography, dry or chemical etching, and lift off techniques, is required. There are different types of materials to represent a waveguide. These materials are polymer linbo3, glass, and SOI. In this paper we have proposed SOI material because it is easily available.
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**III WORKING PRINCIPLE**

Mach–Zender interferometer (MZI) is a ultrasensitive and compact temperature sensor which is based on an in-line Analyze filled-PCF-based sensor. Some Features like electromagnetic interference, fast response; high sensitivity, compactness and robustness are present in MZI construction and that factors which bring photonic sensors into the spotlight. This MZI is integrated in lab-on-chip diagnostics and provides the facility to perform some operation for point-of-care capacity at an inexpensive cost. There are two core modes for MZI configuration. The two cores modes are LP01, LP11 modes and these two modes are usually utilized as optional arms to form inline.

There are many processes to fabricate the 3D waveguide. The listed processes are Micro fabrication techniques, including photolithography, dry or chemical etching, and lift off techniques.

In order to design and fabricate proper waveguides, using of accurate materials and right processes is very much essential. The effective refractive index (Neff) of the waveguide mode is changed because of changing in the ambient refractive index via the passing field interaction. This phenomenon implies the working principle of interferometer.

\[
\Delta N_{eff} = \frac{\Delta N_{eff}}{\Delta n_{ambient}} \tag{1}
\]

\[
s = \frac{2\pi N_{eff}}{\lambda} \tag{2}
\]

\[
\Delta \theta = \frac{2\pi}{\lambda} N_{eff} \tag{3}
\]

\[
\Delta I = \frac{1}{2} (1 + \cos \Delta \theta) \tag{4}
\]

MZI device is constructed with the help of Silicon-on-insulator (SOI) material [6]. MZI waveguides comprising two slots wave guide such as Strip waveguide and slot wave guide. In order to achieve a high sensitivity, MZI uses slot waveguide instead of conventional sensor of a sensing path [7]. MZI can have four parts. The four parts are named as coupled separated section, tapered waveguide section, input straight waveguide and isolated separated section. There is one branching section in the coupled separated section and that makes an alpha angle. This alpha angle has advantages in determining power loss at the output of strip wave guide. Strip wave guide is used as reference arm and sensing arm is slot wave guide.

**IV. SENSOR DESIGN**

Design description for MZI:

| Tool of Simulation | Beam prop |
|--------------------|-----------|
| Wave length of the excitation | 1.55μm |
| Width of component | 5 |
| Index of background | 1.46 |
| Index difference | 1.98 |
| Dimension | 3-dimension |

Strip waveguide implies the reference arm and a slot waveguide implies the sensing arm. We have proposed and designed MZI sensor as a chemical sensor. Consider the configuration it is fragmented that light is tied into a strip waveguide and divided into two arms with a Y junction and recombine again after certain distance [7-9]. The intensity modulation is caused by the interference of light traveling through two arms of the interferometer of the waveguide.

**Fig. 1: Main block diagram of MZI**

**Fig. 2: Basic Structure**

MZI is about 7 nm which is shown in figure 2. By using Beam-prop technology, the sensor MZI is designed [9]. If there is change in designed value that causes the fabrication error variation in terms of width of waveguide.

**Fig. 3: Structure of MZI is designed in contour map.**
V. RESULTS AND DISCUSSION

Graph 1: Propagation of the light through the sensor and observed Power without coating (absence of R.I value) for both the Arm.
After applying the RI value choldran, there is power change in the Mach Zender chip.

Graph 2: Power observed and reduced to 22 %
Applied ri value ddt to the sensing arm

Graph 3: Power observed and reduced to 38%
Applied ri value of phorate to the sensing arm

Graph 4: Power observed and reduced to 48%
Applied ri value of malathion to the sensing arm
he sensor will be very much useful based photonic device which is useful in examining the chemical, pesticide or organic substances that are present in fruit drinks, soft drinks and food. In this paper we have proposed a sensor which is able to detect the chemical, pesticide or organic substances that are present in fruit drink, soft drinks or food.

Different Chemical Substance of RI value | Observed power
---|---
Choldrane | 22 %
DDT | 38 %
Phorate | 48 %
Malathion | 50 %
HCH | 42 %

From table 1-II, it is observed that different RI value is applied to the sensor and there is changes in the power observation which means by observing the power, different chemical substances is detected through designed sensor. Intensity analysis is also done by varying the RI value of chemical substances.

Table-III: Based on different RI value of pesticide present in soft drinks power, intensity is observed by using ∆Ø and ∆Neff value.

| Name of the Sample | ∆Ø in radians | ∆Neff | Power | Intensity (AI) |
|---|---|---|---|---|
| Choldrane | 66.4238 | 3.443426 | 22% | 0.2192 |
| DDT | 66.2707 | 3.443698 | 45% | 0.3932 |
| Phorate | 66.3727 | 3.443177 | 48% | 0.4697 |
| Malathion | 66.3216 | 3.443707 | 50% | 0.6158 |
| HCH | 66.526 | 3.443744 | 42% | 0.2999 |

VI CONCLUSION

In this paper we have proposed a sensor which is able to detect the chemical, pesticide or organic substances that are present in fruit drinks, soft drinks and food. Band gap engineering, that is varying the band gap appropriately in a device and the `intensity engineering`, varying the phase difference appropriately in a device. Both can easily be achieved by adjusting the composition of semiconductors, that is, by using silicon material. We have demonstrated an optical sensor consisting of silicon on insulator Mach–Zender interferometer. By changing the RI value of analyte of the waveguide sensing arm, thereby changing the refractive index of the sensing arm to modulate the intensity of output light. To observe the intensity by use of N effective value from the design, we proposed silicon based photonic device which is known as MZI. In this paper we have observed the transmitted output power when we used different RI value of chemicals. By observing the intensity and output power at the sensing arm of the sensor, the chemical substance is detected. This proposed sensor will be very much useful in examining the chemical, pesticide or organic substances level which is present in fruit drink, soft drinks or food.

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REFERENCES

1. Shan Liu, Krzysztof Switkowski, Chenglong Xu, Jie Tian, Bingxia Wang, Peixiang, Wieslaw Krolkowski & Yan Sheng, “Nonlinear Wavefront shaping with optically induced three-dimensional nonlinear photonic crystals”, Nature Communications Volume 10, Article number: 3208 (2019)
2. Guido Magazza, Sergio Saponara, “Design of a radiation-tolerant high-speed drive for Mach Zender Modulators in High energy Physics”, 2018 IEEE International Symposium on Circuits and Systems(ISCAS)Year:2018, Publisher: IEEE 978-5386-4881-4/18
3. Shuna Lia, b, Jiasheng Liu a, Zheng Zheng a and Xin Lia b Jia Xia a, “ A Novel Modified Mach-Zender Interferometer For Highly Sensitive Sensing”, 978-1-4577-0733-9/12/$26.00 ©2012 IEEE, pp520-521
4. Sumit Sharma a, Krishnendu Chakraborty t, Sudip Roy, “On Designing All-Optical Multipliers using Mach-Zender Interferometers”, 2018, 21st Euro micro Conference on Digital System Design, 978-1-5386-7377-5/18/$31.00 ©2018 IEEE pp672-679
5. H. Zhu, J.D Sutter and U. Sun, “Sensitivity optical biosensor for unlabeled targets”, Anal. Chim. Acta 620, 8-26 (2008)
6. Y. Tian et al., “Direct XOR/XNOR logic Gates using U to U Wave guide and Two Microring Resonator”, IEEE Photonics Technology Letters, vol. 25, no. 1, pp. 18–21, 2013.
7. H. Hazura, A. Hanim, B. Mardiana, and P. Menon, “An analysis of Silicon waveguide phase modulation efficiency based on carrier depletion effect,” in Semiconductor Electronics (ICSE), 2010 IEEE International Conference on. IEEE, 2010, pp. 348–350.
8. T. kuhler and E. Griese, et al., “Modeling the ion exchange process to support the manufacturing of optical multimode graded index waveguide in thin glass sheets in Signal Propagation on Interconnects (SPI), 2010 IEEE 14th Workshop on. IEEE, 2010, pp. 87–89.
9. A. cosentino,q,Tan, Roussy, and H.P Herszug, “Planner integrated sensor on waveguides for sensing application,” in SPPS the 5th International Conference on Surface Plasmon Photonics 2011, no. EPFL-CONF168981, 2011.
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