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REVIEW ON WAVEGUIDE GRATING BASED SENSORS

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ABSTRACT

Photonics is said to be a ubiquitous technology as it allows light to travel faster than the electrons used in electronic chips. An optical integrated circuit is a circuit formed by integrating a laser diode, functional components, interconnecting waveguides, and photodiode detectors on a single substrate to carry out a function. The functional components here include modulators, switches etc. In this paper an effort has been made to review various existing papers related to rib waveguide, gratings on waveguide and various optical sensors which are existing and are in use.

Keywords: Photonics, Rib Waveguide, Gratings, Sensors

I. INTRODUCTION

The role of light has momentous impact in our lives today. The significance of light is vital to most aspects of our society and it cannot be taken for granted. It is used everywhere and has a wide range of applications in various domains like telecommunication for data transmission, medical filed for image processing, transportation, entertainment, clothing etc. Light in simple terms is nothing but a series of electromagnetic waves which has particle behavior under certain circumstances. The word photonics emanates from a Greek word phos which means light. Photonics is closely related to optics and is analogous to electronics. It is innovating the 21st century like electronics in the 20th century. Photonics is said to be a ubiquitous technology as it allows light to travel faster than the electrons used in electronic chips. There is an exponential growth in the research activities in the field of photonics and optics over the years because of its wide range of application in various domains. An optical integrated circuit is a circuit formed by integrating a laser diode, functional components, interconnecting waveguides, and photodiode detectors on a single substrate to carry out a function. The functional components include modulators, switches etc. The integration is performed in order to obtain a constant and packed in optical system.. The non failure of these hollow waveguides encouraged the scientists to create waveguides in the infrared region of the electromagnetic spectrum. They were primarily used for medical purposes, but later extended to other areas of applications. The waveguide directs or guides the waves in a comparable way like the river banks head a tidal wave. The basic structure of a waveguide is shown in Figure.1, where the indices of the cladding layer, and substrate are n_c, and n_s, respectively.

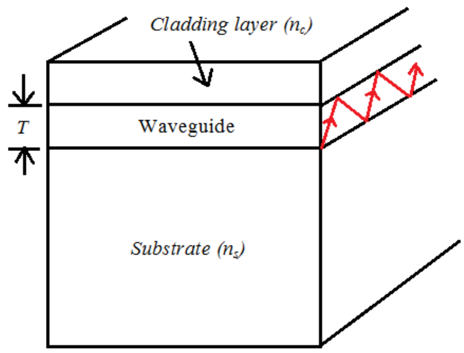

Figure: 1 Basic structure of a waveguide.

The waveguides design and fabrication using right materials and process is important since it plays a prominent role in the circuit and it is also said to be the main building block of an optical circuit. It can be thought as a metal tube which is hollow and is used to connect components and devices since it is of low loss light propagation. The light is said to be restricted in the guiding layer to satisfy the condition $n_f > n_s > n_c$. A waveguide can also be defined as a cylindrical structure which is used for guiding the flow of electromagnetic wave in a way parallel to its axis, impounding it to a region either within or neighboring to its surfaces. Channel waveguides restrict the light in two dimensions of the order of the wavelength, and, in general, the refractive index n (x, y) is a function of both transverse coordinates x, y. Channel waveguide consists of two types of which the rectangular waveguides are the most commonly used non-planar waveguides for device purposes. Channel waveguides include many waveguides such as buried waveguides, strip-loaded, ridge, rib, diffused, slot, ARROW, and so on

II. LITERATURE SURVEY

G Sowmya Padukone and H Uma Devi have proposed "*Tumor Markers for Cancer Detection using Optical Sensor"* [1]. In this work an optical bio sensor has been designed for the detection of cancer in the regions of brain, renal and lungs. Initially, the author speaks about the various existing methods for the detection of the cancer cells and then tells about the design they have proposed. The work is carried out using the MEEP tool which gives Quality factor of normal cell as well as cancerous cell. This detection helps in saving many lives of the people and thereby increasing their lifespan.

Shankar Kumar Selvaraja and Purnima Sethi have proposed "*Review on Optical Waveguides*" [2]. In this chapter the reviews about the optical waveguides and their taxonomy based on the geometry such as Non-Planar and Planar waveguides and their type like Wire, Strip loaded, Buried Channel, Rib, Diffused, Slot and based on refractive index such as Gradient or Step Index, mode propagation such as Single or Multimode and material platform such as Polymer or Glass or Semiconductor, etc. A meticulous analysis of waveguides and their comparison realized in different material platforms along with the propagation loss is discussed here. In the final conclusion a comparison is drawn between different waveguide platform as a function of index contrast and compactness.

Michael Bulk proposed "*lon Implanted Bragg Gratings in Silicon-on Insulator Rib Waveguides*" in 2005 [3]. This thesis work mainly focuses on the Ion implanted Bragg gratings which were integrated on rib waveguide structures. This is the first time where ion implantation has been utilized in order to produce Bragg gratings integrated on a SOI rib waveguide. The simulation, fabrication and characterization have been done for the silicon-on-insulator platform. The benefits of using implanted Bragg gratings compared to other gratings is that it includes planar surface retention and is desirable for subsequent processing and wafer bonding. Device performance here has been simulated by making use of coupled mode theory (CMT) in conjunction with beam propagation methods (BPM), to find out the transverse modal profiles for evaluating the coupling coefficients as well as to determine geometric dimensions which are appropriate for achieving an adequate grating strength and single-mode operation. The results obtained tells that the strength of the implanted gratings were approximately 2.5 times stronger compared to etched gratings with similar dimensions and also the implanted Bragg gratings greatly increased the device packing density while achieving the same level of functionality as that of the etched grating.

Chandrika T N proposed "*Design and Analysis of Integrated Optic Waveguide Grating for Sensor and Communication Applications*" [4]. In this work application and importance of the waveguide gratings in the field of sensor domain and optical communication is discussed. Waveguide gratings are used for massive amount of applications because of various reasons like high sensitivity, immunity to electromagnetic interference, light weight etc. Here Waveguide gratings on SOI (Silicon-on-Insulator) platform are considered for the reason that it has numerous advantages in distinction to other materials like Lithium Niobate etc. Also in this thesis, design and analysis of various structures of waveguide gratings and their characterization is done. The future work of this thesis lies in the fabrication of the devices on which study and analysis were carried out.

Souren Pogossian, Lili Vescan, and Adrian Vonsovici have proposed "*The Single-Mode Condition for Semiconductor Rib Waveguides with Large Cross Section*" [5] .This paper deals with the comparison of the single-mode condition for the rib waveguides with large cross section obtained by the effective index method and the corrected formula proposed by Soref [10]. Result obtained tells that the effective index method is in a better agreement than the modified version.

Bahram Jalali, Fellow and Sasan Fathpour have proposed "*Silicon Photonics*" [6]. In this paper overview of silicon as a promising choice of material for the photonic industry is given and an attempt has been made to know about the current state of the device technology and how silicon can be used as a material for modulator, amplifier and lasers and its advantages and disadvantages are discussed. Various properties of the silicon like thermal conductivity and liner properties of the silicon are highlighted which opens up the opportunity to a new group of mid-IR photonic devices and also the challenges which are required to face in order for the large scale commercialization are given out. Few of which include use of silicon in an economic way and the heat issues which exist when the silicon material is used. The study has also given out that silicon material does not translate into low cost for a single device but lost cost can be achieved during large scale production and the power dissipation is said to be large particularly in the modulator and amplifier devices designed on the silicon material.

Siti Sarah, Sawal Hamid, P.Susthitha Menon, Nurjuliana Binti and Md Shabiul Islam have proposed "*Implementation of SOI-Based Rib Waveguide for High-Speed Optical Interconnect*" [7]. This paper focuses on the design of optical waveguides and the optimization to be used in the Optical Interconnect links. Here a single mode condition for SOI-based rib waveguide has been presented for high-speed Optical Interconnect implementation at a circuit level. The main reason for using the SOI platform is because of its cost effectiveness and high quality. The rib waveguides here are made into a single mode condition (SMC) by setting the dimension of rib height, depth, and width. The simulation results obtained in this paper shows that the effective index n_{eff} increases with r, where r is said to be the ratio of the slab height to the rib height. The waveguide performance of the OI links such as output power, propagation loss and propagation delay has been evaluated on OptiSPICE.

Veer Chandra and Rakesh Ranjan have proposed "*Analysis of Propagation Loss in Silicon-on-Insulator based Photonic Rib Waveguide with Small Cross Section*" [8]. In this paper, work has been carried out on the Rib waveguide which is said to be the most popular structure used to design the photonic waveguides and sensors. The main limitation related to the Rib waveguide is its propagation loss. In an optical waveguide the main sources of propagation loss are absorption within the materials and scattering loss from the sidewalls etc. In this work, propagation loss in the Rib waveguides has been reduced to a significant low value by optimizing waveguide geometry. Here for w = 500 nm and 1000 nm, at $\lambda = 1.55$ µm a minimum propagation loss of 0.23 dB/cm and 0.1 dB/cm have been obtained. To validate the obtained results, the analysis has been extended with some other parameters, such as propagation length, effective refractive index (real) and confinement factor. Depending on what area the Rib waveguide is said to be used, one can further optimize the propagation loss. All the simulation results in this work have been performed by COMSOL simulation software based on finite element method.

Dengpeng Yuan, Ying Dong ,Yujin Liu and Tianjian Li have proposed "*Mach-Zehnder Interferometer Biochemical Sensor Based on Silicon-on-Insulator Rib Waveguide with Large Cross Section*" [9]. In this paper Mach-Zehnder interferometer biochemical sensing platform based on Silicon-in-insulator rib waveguide which has a large cross section is proposed. The field intensity,mode polarization and cross section dimensions of the SOI rib waveguide are optimized by making use of finite difference method (FDM) simulation. The reason for using SOI rib waveguide with large cross section is for high coupling efficiency which enables the waveguide sensors to easily integrate with optical communication systems as well as electronic systems. The performances of the MZI sensing platform results are obtained by using 2D-FDTD method.

Richard A. Soref, Joachim Schmidtchen, and Klaus Petermann have proposed "*Large Single-Mode Rib Waveguides in GeSi-Si and Si-on-SiO$_2$*" [10]. In this paper Mode matching and beam propagation methods are carried out in to order to analyze the single mode operation of optical GeSi-Si and Si-$Si0_2$ semiconductor rib waveguides. The author has found out the waveguide dimensions which will allow only the fundamental HE_{00} or EH_{00} mode to propagate in this work. For both material systems it has been found out that the rib can be several microns wide and several microns high, thereby allowing efficient coupling to single-mode fibres.

Richard Soref proposed "*Silicon photonics technology past, present and future*" [11]. This paper deals with the advances in silicon based photonic components such as waveguides, high speed modulators, switches etc. It also focuses on the photonic structures that are amenable to Si-based optoelectronic integration. Here science and technology trends that are up coming in the photonic device construction are identified and in device related Group

IV materials science and new wavelength ranges available for photonic circuit operation are also discussed. It also tells that Photonic crystal devices will contribute valuable functions to the Silicon PICs of the future and the on-chip convergence of Silicon micro photonics, plasmonics and nanophotonics will lead to a more compact photonic device.

Y. Liu, P. Hering and M. O. Scully proposed "*An integrated optical sensor for measuring glucose concentration*" [12]. In this work, author has designed an optical sensor with MZI interferometer waveguide and optical fibers. This particular sensor is designed to measure changes in the sugar concentration which is helpful for people dealing with diabetics and hypoglycemia. This sensor works on the basic principle that refractive index varies linearly with respect to concentration of sugar in a sugar solution. Here the sensor is said to be combined with MZI waveguide and optical fiber where one arm of interferometer is clad with glue which serves as a reference and another arm is exposed to sugar solution, both the arms are kept isolated from each other. The output signal which is obtained from one arm of interferometer is now varied as the concentration of the sugar solution.

Jenq-Nan Yih, Yi-Ming Chu, Yen-Chieh Mao, Wei-Han Wang, Fan-Ching Chien, Chun-Yu Lin, Kuang-Li Lee, Pei-Kuen Wei, and Shean-Jen Chen proposed "*Optical waveguide biosensors constructed with sub wavelength gratings"* [13]. In this work in order to analyze bio molecular interactions the reflection and resonance spectrum of a sub wavelength grating waveguide is said to be used. Whenever bio molecular interactions occur there is said to be a shift in the resonance wavelength. The author has made us of GSOLVER software to compute the resonance spectrum of the sub wavelength grating waveguide. The designed and fabricated biosensor here has a detection limit of 10^{-5} refractive index units.

Vittorio M. N. Passaro *, Corrado de Tullio, Benedetto Troia, Mario La Notte, Giovanni Giannoccaro and Francesco De Leonardis proposed "*Recent Advances in Integrated Photonic Sensors"*[14].In this work the author explains the various advantages and applications of using photonic sensors in various fields. Here initially an explanation is given on the various principles on which a photonic sensor works, which includes the homogenous sensing, Raman scattering, surface sensing etc. A complete review on the photonic sensors for biochemical and chemical detection is presented here which includes the sensors based on ring resonators, Mach-Zehnder Interferometer,photonic crystals and directional couplers. Photonic sensors application for angular velocity measurement and electric field measurement is presented here.

III. CONCLUSION

In this paper an effort has been made to review various existing papers related to rib waveguide, gratings on waveguide and various optical sensors which are existing and are in use. This preliminary work is necessary in order to continue any work on waveguide grating based sensor. Here an overview of papers related to what a waveguide is and how they are classified, the single mode condition in case of a rib waveguide, how silicon plays a major role in fabrication of waveguides and the various biosensors based on different applications is presented.

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