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A REVIEW ON RING RESONATOR BASED SENSORS

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ABSTRACT

Photonics is the science of generation, detection and manipulation of light through sensing, signal processing etc. A circuit that is formed by the integration of functional components, laser diode, waveguides etc to perform a specific function is known as an optical integrated circuit. In this paper an effort has been made to review various existing papers related to ring resonators, micro cavities and various optical sensors that exist and are currently in use.

KEYWORDS: Photonics, Ring Resonator, Micro cavities, Sensors

I. INTRODUCTION

Light is what makes the visibility possible and hence place a very important role. Light is nothing but an electromagnetic wave that has a wave or a particle kind of behavior. Photon is the basic unit which makes up the light. Photonics has an advantage over electronics because the speed of the photon is incomparably faster than that of the electron. Waveguides are the building blocks of integrated optical circuits In this paper the ring resonator based sensors has been reviewed. Ring resonator is a set of waveguides in which at least one waveguide has a curved or ring shape. Ring resonators have small foot print, high integration density, stable alignment and hence are suitable to be used in the integrated circuit. Figure.1, shows the schematic of the ring resonator .

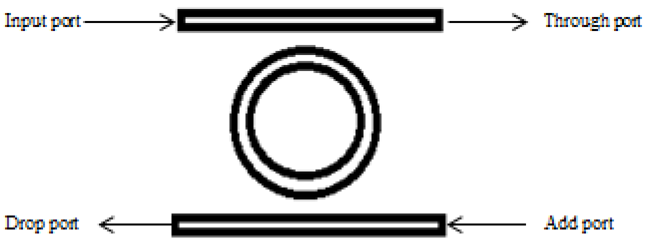

Fig-1: Schematic of a Ring Resonator**.**

The ring resonator discussed in this paper is fabricated on silicon on insulator platform, because silicon is abundantly available in nature and batch fabrication can be done using CMOS process. Waveguide 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. Ring resonators can be used as filters also. Three types of coupling occur in a ring resonator and the coupling depends on the distance, coupling length and refractive index contrast. Spectral characteristics of the ring resonator are free spectral range, Full width half maximum, resonant wavelength and quality factor.

Sensor is a device which measures the physical environment and provides an output. Sensors can be designed using ring resonator for bulk sensing and surface sensing. The racetrack shaped ring is used for surface sensing purposes and the bioanalyte is detected at the surface of the waveguide.

II. LITERATURE SURVEY

Liaquat Ali, Mahrukh Khan, Mahmood and Abdul have proposed "*High quality silicon photonics optical Ring Resonator Biosensor Design*" [1]. In this paper, an optical ring resonator in silicon photonics has been designed for breast cancer detection. The designed sensor will function by identifying the variations in light in the sensor which is circulating and the matter i.e., an antibody present on the surface of the sensor used in case of breast cancer . The refractive index change results in the change of the resonant wavelength of a ring resonator. This gives the performance of a ring resonator as a sensor. Here the simulations are carried out by changing the radius of the resonator for respective antigens and antibodies. In this for the fabrication purposes silicon has been used, which is abundantly available in the nature. Ring resonator is incredibly sensitive to refractive index change. This paper proposes a design for cancer biosensor which incorporates ring resonator and it uses surface grating coupler. The spectral response has been shown for multi wavelength laser. Taylor expansion has been used for the computation of effective index of the waveguide. Various parameters are considered for the modelling of the ring resonator. They are obtained by waveguide simulation using this a circuit is built in the Lumerical Interconnect from which the spectral response for the designed ring resonator is obtained. The improvement in the proposed biosensor can be seen as compared to conventional biosensor. 5μm is the radius of the proposed ring resonator and it has a band gap of 0.1μm. It gives a better quality factor and moderate extinction ratio. For the fabrication purposes electron beam lithography technique has been used.

Ritu Raj Singh, Soumya Kumari, Abhinav Gautam, Vishnu Priye proposed "*Glucose Sensing Using Slot Waveguide Based SOI Ring Resonator*" [2]. In this paper, for the purpose of bio sensing a sensor based on an optical ring resonator has been proposed. The application is for the blood samples that has glucose levels in the range of 10 mm/dl to 200 mg/dl. The proposed design is of two methods, one which employs slot waveguide and the other has ridge waveguide and it shows that the sensitivity of the slot waveguide is very much higher than that of the ridge waveguide approximately upto six times. The variations of the glucose level leads to different refractive index which affects the spectral shift of the resonator ultimately. In a rectangular waveguide the interaction between the light and the matter in the cladding is minimal but in a slot waveguide there is high interaction in a slot and the cladding together. In this paper multiple slot waveguides as biochemical sensor has been proposed along with the several parameters of the guide which are optimized to obtain a better sensitivity. Sensitivity and detection limit can be improvised by employing silicon on insulator ring resonator that has a sub wavelength grating. Monitoring the glucose levels often is necessary a sensor makes the measurement of the glucose levels easier is necessary. Quicker and better sensing for glucose detection could be achieved from optical methods. To identify the evaluation of the empty waveguide and the waveguide with sample is considered. The parameters have been optimized for the design. Radius of the waveguides used should be minimal in the design and 1550 ηm is the resonant wavelength used. The ring radius for the ridge waveguide and the slot waveguide used is 35.34μm and 33.5μm respectively. 47.69% confinement can be seen and also shows that in case of sensitivity the slot waveguide offers it the better and provides quick and better results.

Ksendzov A and Y. Lin have proposed "*Integrated optics ring-resonator sensors for protein detection* " [3]. The design of the ring resonator proposed in this paper doesn't necessitate the use of molecular tags. Instead target molecules require specific binding on the surface of the sensor and hence generate a signal. The identification of biomolecules could be improvised by having an array of sensors. For the design purpose Si_xN_y/SiO_2 waveguides are used and this detects protein even in low concentration and offers a detection limit of 0.1ηm in a saline solution that has ηm of avidin. Immobilization of avidin and the specific binding occurs due to the surface biotin coating and the sensitivity of the sensor relies on it. SiO_2layer is required to accumulate the biotin layer at the top. Spectroscopic ellipsometer is used to measure refractive index of the waveguide. By employing racetrack resonators the coupling can be enhanced among straight and bent waveguides segments. The activated chip could be stored for week without any degradation in the activity in a vaccum desicator. Biotin coating is done to the silane sensor. Thermoelectric cooler is used. The proposed design offers low bending loss and higher coupling rate at the cost of higher order modes and it has good sensitivity and wide dynamic range. It is immune to temperature variations. The performance of the sensor can be increased with good coating techniques. If a coating is not uniform the sensor designed will have a poor performance. Ring size should be moderate if it is too small. The amount of sample will also reduce.

Masashi Ohkawa, Tetsuharu Abe, Seishi Sekine and Takashi Sato have proposed "*Integrated optic Micro pressure sensor using Ring Resonator*" [4] .This paper discusses the enhancement of the sensitivity of the micro pressure sensor based on integrated optics. The design employed has adiaphragm on which a portion of the waveguide that belongs to the ring resonator is placed. On application of the pressure on gthe sensor the shape of the diaphragm will be distorted and induces phase shift due to the variation of the refractive index. This shift causes a change in the resonant wavelength that occurs due to the wave confined in a diaphragm. The pressure could be identified due to these changes. To obtain a good sensitivity sensor diaphragm should have a uniform shape and it also need to have a ring resonator in TM mode. In that case underwater sounds which have very low pressure could be detected. Sensors designed optically have small footprint and negligible weight. The optimization of the dimensions of the waveguides employed in the design has been done. The phase variation of the light wave happens due to the application of the pressure. This designed sensor could also be used for other purposes. The sensitivity of the sensor depends on the shape and size of the diaphragm. This proposed paper also explains about the principles on which the performance of the sensor depends. A method to analyse the performance of the sensor is also discussed. The width of the diaphragm should be less. Variations in the temperature in an environment where the sensor is placed could be a problem as it hasn't been tested.

Ishita Bhar, Tapolina Jha, Priya and Sabitabrata Dey have proposed "*Design and Simulation of Integrated Optic Ring Resonator based Devices*" [5]. In this paper, a quadruple optic ring resonator fabricated on silicon on insulator platform whose spectral range is wide and acts as an optical filter has been discussed. The sensors discussed works on the principle of total internal reflection and constructive interference. The design proposed has bus waveguides and at least one curved waveguide. The intensity of the light will be enhanced due to constructive interference. Since light makes multiple round trips inside the ring and hence the delay is induced. The parameter using which the optical coupling could be curbed has been discussed. Using z-transform the analysisnof the characterization of the ring resonator is done and the ring resonator as add or drop filter is shown. Free spectral range and transfer function of quadruple optical ring resonator are expressed mathematically. Computation of group delay, frequency response and dispersion is done using MATLAB. It is always important to have a channel that has a wide bandwidth.

Otto Schwelb has proposed "*Transmission, Group Delay and Dispersion in Single –Ring Resonators and Add/Drop Filters- A Tutorial Overview*" [6]. In this tutorial, the group delay, transmission and dispersion of the building block of an optical filter constructed using ring resonators has been described. The ring resonators in this has a single ring and might have dual port or four ports that is it may have a single bus waveguide or two bus waveguides. Mathematical Expressions to compute various factors of the ring resonator such as quality factor, finesse, bending loss has been given. Comparisons with the different resonators that are available have been made. Various applications of the ring resonator have been explored. Ring resonator will allow only such wavelengths that satisfy resonant conditions. Two port optical networks are of two types, one in which the input signal is reflected back into the port under ideal conditions called as all pass network and they are lossless. Complementary architectures for filters using ring resonators is described and the four ports of the ring resonator is explained in detail. Transfer characteristic of the ring resonators are described based on scattering parameter and the mathematical expression for the same is shown. Relative intenstity transfer and phase delay is derived from these expressions. Channel separation filter can be obtained using the phase characteristics of a ring resonator. Group delay and quadratic dispersion time expressions have been derived and the photonic applications that employ ring resonator are described.

Gun-Duk Kim, Hak-Soon Lee and Boo Tak Lim have proposed "*Silicon Photonic temperature sensor employing a ring resonator manufactured using standard CMOS process*" [7]. In this paper, an integrated optic temperature sensor that has a small foot print has been proposed and this design employs a silicon ring resonator that has a vertical grating coupler. The fabrication is done using a standard CMOS process of 180ηm technology so that it could provide an easier integration to other optic or electronic devices. On monitoring the resonant wavelength shift occurs due to thermal expansion and thermo optic effect. The temperature variations could be calculated. For a waveguide of width 500 ηm, 83pm/c sensitivity was achieved. By varying the width of the waveguide the sensitivity could be improved. Approximately 6μs of response speed was obtained for the designed sensor. Since silicon has temperature invariant properties, it is the desired material for the fabrication of the sensors. In the proposed design the spectral response of the ring resonator seems to be improved. Silicon waveguides are based on high index contrast to satisfy the single mode condition. The waveguide width has been limited to approximately500 ηm. Using the method of the film mode matching measurement of the sensitivity of the sensor has been done. Photo lithography and dry etching processes are used to manufacture the sensor on top of the silicon layer. The manufactured sensor has an advantage of being low cost and better integration.

III. CONCLUSION

In this paper an effort has been made to review literature on ring resonator based sensors, fabrication of the ring resonator and sensitivity of sensor. This review is done in order to further continue the work and to develop a bio sensor. The designed waveguide should be of single mode condition and should offer high sensitivity. Here an overview of papers related to silicon on insulator ring resonator and the choice of the platform for fabrication purposes has been reviewed.

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IV. REFERENCES

[1] Liaquat Ali, Mahmood Uddin Mohammed, Mahrukh Khan, Abdul Hamid Bin Yousuf, Masud H. Chowdhury, "High-Quality Optical Ring Resonator-Based Biosensor for Cancer Detection", *Sensors Journal IEEE*, vol. 20, no. 4, pp. 1867-1875, 2020.

[2] R. R. Singh, S. Kumari, A. Gautam and V. Priye, "Glucose Sensing Using Slot Waveguide-Based SOI Ring Resonator," in *IEEE Journal of Selected Topics in Quantum Electronics*, vol. 25, no. 1, pp. 1-8, Jan.-Feb. 2019, Art no. 7300608.

[3] . A. Ksendzov and Y. Lin, "Integrated optics ring-resonator sensors for protein detection," Opt. Lett. 30, 3344-3346 (2005).

[4] Masashi Ohkawa, Tetsuharu Abe, Seishi Sekine and Takashi Sato "*Integrated optic Micro pressure sensor using Ring Resonator*" ,ISSN8756-663X/96/0004-0001.

[5] I. Bhar, T. Jha, Priya and S. Dey, "Design and simulation of integrated optic ring resonator based devices," *2012 International Conference on Communications, Devices and Intelligent Systems (CODIS)*, Kolkata, 2012, pp. 453-456.

[6] O. Schwelb, "Transmission, group delay, and dispersion in single-ring optical resonators and add/drop filters-a tutorial overview," in Journal of Lightwave Technology, vol. 22, no. 5, pp. 1380-1394, May 2004.

[7] Gun-Duk Kim, Hak-Soon Lee, Chang-Hyun Park, Sang-Shin Lee, Boo Tak Lim, Hee Kyoung Bae, and Wan-Gyu Lee, "Silicon photonic temperature sensor employing a ring resonator manufactured using a standard CMOS process," Opt. Express 18, 22215-22221 (2010)