Moems based Micro Accelerometers Sensor Sensing Structures

Sundar Subramanian, Thangadurai. N, K. Gopalakrishna

Abstract: ***Optical MEMS based micro accelerometer integration of mechanical, electronics and optical system is having ability to sense and convert many physical quantities. In the proposed work the accelerometer based sensing structures in photonic crystal configuration is analyzed. Radius of hole and rods in photonic crystal configuration is varied from 0.17µm to 0.19µm and dielectric constant of configuration is varied to Gallium Arsenide, Indium Phosphate and Silicon materials. Remarkable frequency shift in photonic crystal configuration and high quality factor of 7212 is observed for the selection of silicon material. Analysis is carried for sensing structures in two configurations of photonic crystal called rods in air and holes in slab. This proposed work having an extensive scope in automobile and inertial navigation in future.***

Index Terms: MEMS, GaAs, HIS, RIA, Accelerometer.

I. INTRODUCTION

Key growth direction of sensor is its miniaturization. Most reliable and trustable micro sensor is micro electro mechanical system based devices. Micro sensors based on micro electromechanical system is totally different from traditional sensor in view of material, methods, application etc. Micro accelerometer miniaturized small size inertial measurement system with measurement of acceleration and deceleration. Integration of microelectronics, micro optics, mechanical system brings out the new area to explore is MOEMS i.e. Micro Electro Mechanical System [1]. MOEMS complete integration of photonic waveguides, semiconductors, light sources and data monitors. Because of MOEMS devices having variety of benefits like insensitive to electromagnetic interference, reduction in size, Process able to mass production, miniaturized sizes it can be usable in many advanced science and technology product like biomedical systems, agricultural sensing system, Automobile, home automation and security systems. Micro Electro Mechanical system usually converts non-electrical signal to electrical signal, so there should be continuous power source if it has to be used in any application, in this way consumption of power is more [2]. But integrating the optics with MEMS will reduce the power loss because light as medium in MEOMS sensible for mechanical actuation and delivers the output with less integrated electrical circuits. Whole sensor system comprises two level of fictionalization i.e. sensing layer to computation circuit and array of sensor system [3]. In the sensor array system there will be combination of similar type of sensor will assist in detection of different bio/chemical samples at one stretch, so same array system can be used in multiple tasks. MOEMS bases sensor system mainly consist Micro sensor, transduction unit, actuator system and data analyze All these components together put forth the MOEMS based accelerometer sensor. Developed MOEMS based sensor in the field of Biomedical System, Health Monitoring based intelligent sensor and aerospace for structural monitoring and automobile safety has revolutionized human life to high level of living [4]. MOEMS based sensing system undergoes sophisticated fabrication process [5]. Initially photo sensitive sensing layer deposited the process is called resist. In the next step structures decided during the design and simulation is defined with the help of lithography technique [6]. In the later stage structures are etched by the process of etching with the different chemicals. Cladding layer has to be deposited with the prior parameters specification. In most of the case electron beam lithography, optical UV lithography and focused Ion beam techniques are used to develop for exposing to deep UV. MOEMS uses specific manufacturing technologies i.e. LIGA and micro mechanical processing [7]. Micro machining technology involves two process i.e. bulk micro matching and surface micro machining. Most of MOEMS devices undergo wet etching and dry etching is the bulk micro machining processes. Most effort towards development of micro accelerometer based MEMS techniques have seen from last decades. A great variety of Micro Opto-Electro Mechanical System based devices such as pressure sensor; displacement sensor and accelerometer sensor are in developing stage. In micro accelerometer based optical MEMS mainly consist of Mass block and movable system and sensing system [8]. Mass block which is vibrating due to acceleration and sensing finger attached to vibrating block is undergoes continuous deflection. Sensing finger is deflecting in the waveguide region of optical systems will detect the changes from light media and provides the necessary output. In the proposed work here it has been shown interest towards optimization of different MOEMS based accelerometer structure for improvisation of quality factor from optical analysis is used to quantify the light decay during the sensing arm deflection in the waveguide region in optical system i.e. photonic crystal.

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Different photonic crystal configurations like holes in silicon slab and silicon pillars in air also considered during the analysis.
Other parameters considered during the analysis was radius of rods and holes, and three different materials i.e. silicon, gallium arsenide and Indium Phosphate. Sensitivity is analyzed with respect to all specified parameters.

II. OPERATION AND WORKING PRINCIPLE

Proposed work consists of optimization of optical MEMS based sensing arm for accelerometer sensor application. The structure optimized with respect to aspect ratio, photonic crystal configuration, material and displacement ranges. Sensitivity changes during optimization are calculated and amount of light decaying in cavities and waveguide is quantified. Sensing arm for the photonic crystal waveguide region has been designed which is incorporated with mass block also called vibration block (Fig.1a). Due to vibration in the block sensing arms will get deflected, MOEMS based sensing arms which deflects in the waveguide region will brings out the overall changes in effective refractive index changes. This change in refractive index mediated with the help of optical medium which is obtained by laser light source in waveguide region. This structure showcase case the micro size single slab in ring resonator structure.

Parameters considered during the analysis
Lattice constant = 1µm
Radius of rod/hole as shown in the Table 1
Light source = Gaussian pulse, pulse width = 0.13µm
Width of waveguide = 0.18µm;
Centre frequency used = 0.3225
Lattice configuration = square
Dialectic constant; Si = 12, GaAs= 11.74, InP = 10.01

Table 1: Parameters considered during the analysis

Type of Structure	Radius of Rod/Hole	Photonic Crystal configurations	Material Considered	Displacement Range
Resonator	0.16 µm to 0.19 µm	1)Holes in Slab 2)Rods in Air	Si, GaAs, InP	0.1 µm to 0.5µm

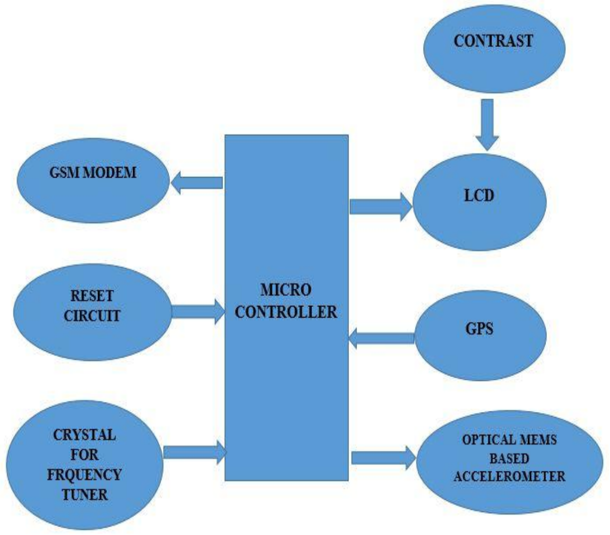

Fig 1(a): Schematic Block Diagram of Optical MEMS accelerometer for automobile

Basic acceleration modules consists of mass block, spring and damper system (Fig. 1b)

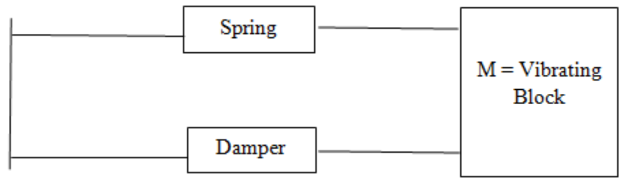

Fig.1 (b): Basic acceleration module

L(s) = X(s)/D(s) = 1/ (s^2+D/M(s) +K/M = 1/s^{2+}+W/Q(s) +W^2----------------[2]

Equation [2] is the transfer unction for acceleration to displacement. Table 1 shows the analysis setup in proposed work

III. RESULT AND DISCUSSION

In the proposed micro accelerometer based on optical MEMS, measures acceleration by measuring the displacement of moving slab and force applied. Micro accelerometer measures acceleration with the help of mass attached to moving slab or finger. Intensity modulation within the photonic crystal brings out the frequency shift in data monitor. Intensity is varied by the movement of slab. According the Newton's second law saying force on the vibrating block measures the acceleration.

F= ma -- [1]

$$a = {dx^2}/{dt^2} = dv/dt,\ v=dv/dt;\ v= dx/dt$$

Resonator Structure

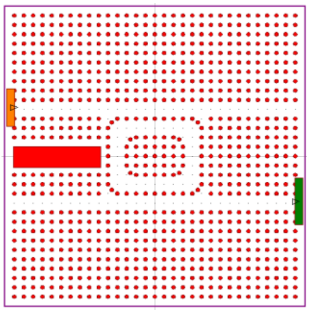

Fig 2: Structure

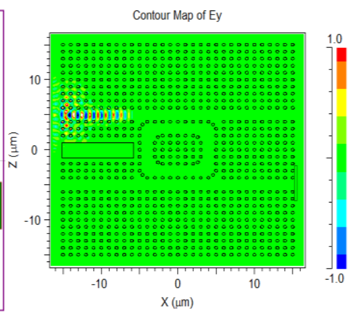

Fig 3: Light propagation

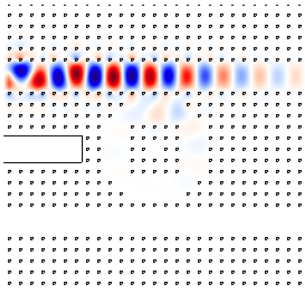

Fig 4: Light propagation

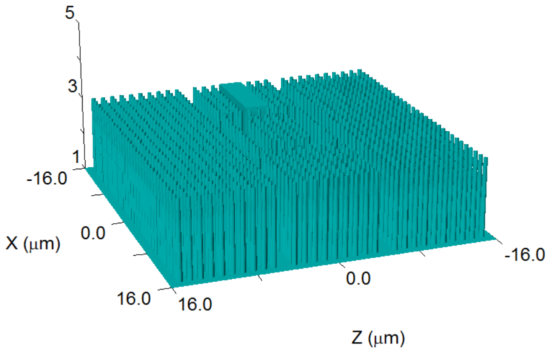

Fig 5: 3D diagram of Structure – RIA

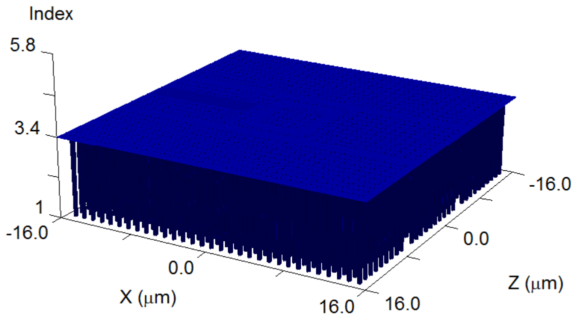

Fig 6: 3D diagram of Structure - HIS

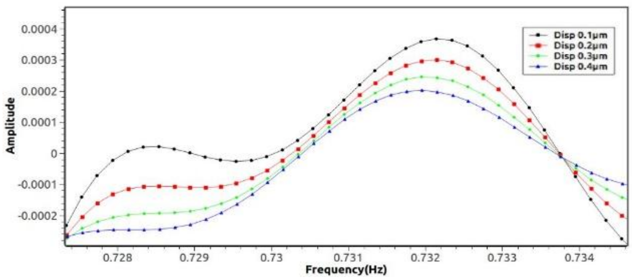

Fig 7a

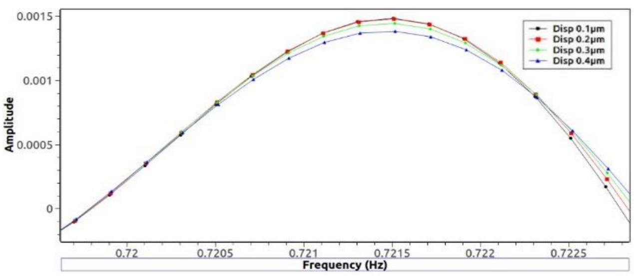

Fig 7b

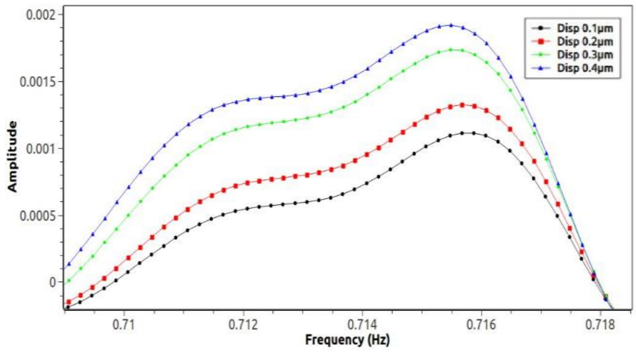

Fig 7c

Fig 7A, 7b, 7c: Shows Sample frequency shift for 0.17µm aspect ratio in RIA configuration for GaAs, Inp and Si

Table 2: Frequency shift for 0.76µm aspect ratio in RIA configuration for GaAs

Sl. No	Displacement (µm)	Frequency Shift	Amplitude
1	0	0.731	0.0001
2	0.1	0.7314	0.0002
3	0.2	0.7316	0.0003
4	0.3	0.7318	0.0004

Table 3: Frequency shift for 0.17µm aspect ratio in RIA configuration for InP

Sl. No	Displacement (µm)	Frequency Shift	Amplitude
1	0	0.7210	0.0010
2	0.1	0.7218	0.0012
3	0.2	0.7220	0.0013
4	0.3	0.7221	0.0014

Table 4: Frequency shift for 0.17µm aspect ratio in RIA configuration for GaAs

Sl. No	Displacement (µm)	Frequency Shift	Amplitude
1	0	0.7140	0.0005
2	0.1	0.7143	0.0008
3	0.2	0.7144	0.001
4	0.3	0.7146	0.0014

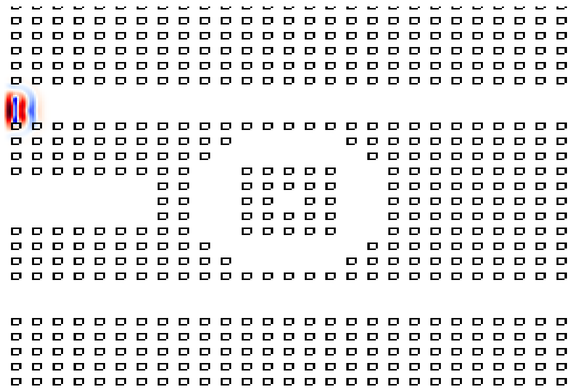

Fig 8: Resonator structure in HIS configuration

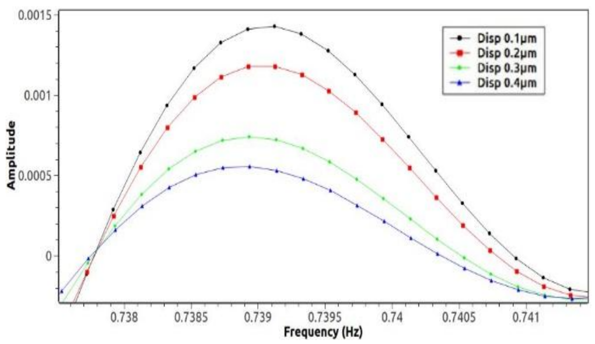

Fig 9a

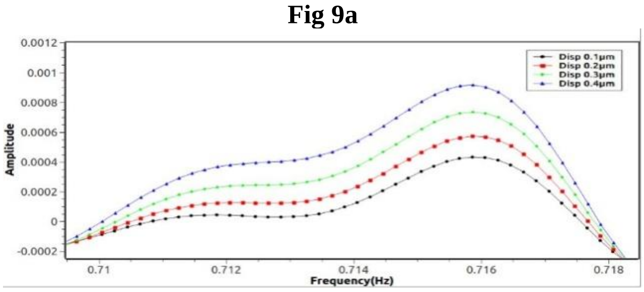

Fig 9b

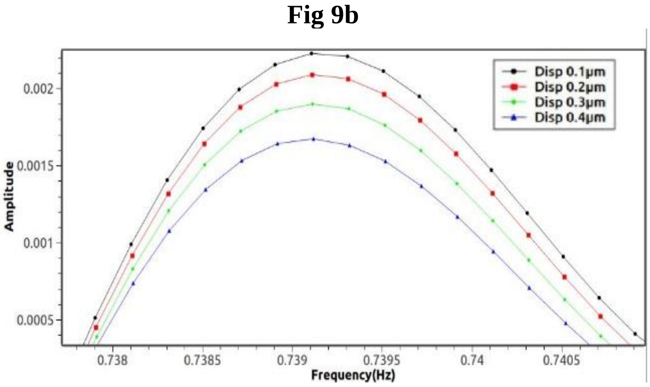

Fig 9c

Fig 9a, 9b, 9c: Shows Sample frequency shift for 0.17µm aspect ratio in HIS configuration for GaAs, Inp and Si

Table 5: Frequency shift for 0.17µm aspect ratio in HIS configuration for GaAs

Sl. No.	Displacement (µm)	Frequency Shift	Amplitude
1	0	0.7386	0.0005
2	0.1	0.7387	0.0008
3	0.2	0.7388	0.0009
4	0.3	0.7389	0.0010

Table 6: Frequency shift for 0.17µm aspect ratio in HIS configuration for InP

Sl. No.	Displacement (µm)	Frequency Shift	Amplitude
1	0	0.7160	0.0002
2	0.1	0.7161	0.0004
3	0.2	0.7162	0.0006
4	0.3	0.7163	0.0008

Table 7: Frequency shift for 0.17µm aspect ratio in HIS configuration for Si

Sl. No.	Displacement (µm)	Frequency Shift	Amplitude
1	0	0.7390	0.0015
2	0.1	0.7392	0.0018
3	0.2	0.7393	0.0019
4	0.3	0.7394	0.0020

The structure is considered for analysis in the aspect ratio of 0.17µm, 0.18µm and 0.19µm in materials like GaAs, Indium phosphate and Silicon for Holes in Slab and Rods in Air configuration. Remarkable frequency shift and high quality factor of 7212 is observed during the sensing in rod in air sensing configuration. Fig 2 to Fig 9c shows sensing structures in PhC configuration and frequency shift obtained for different displacement in the range of 0 to 0.3µm. Table 2 to Table 7 shows frequency and amplitude results obtained for PhC configurations. Fig 10 and Fig 11 depicts the quality factor obtained for holes in slab and rods in air Phc configuration for three different types of material in different aspect ratio and displacement range

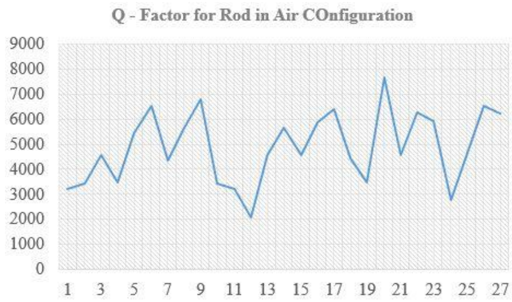

Fig 10: Q factor in RIA configuration

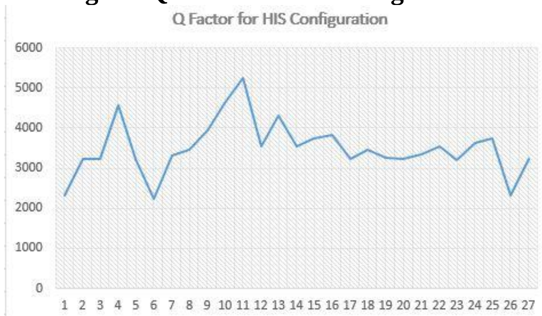

Fig 11: Q factor in HIS configuration

IV. CONCLUSION

In this proposed research work, the optimization of micro accelerometer based sensing structures demonstrated. Here, we considered three types of sensing structures in three different types of material i.e. GaAs and InP, Si in three range of aspect ratio 0.17µm, 0.18µm and 0.19µm for different photonic crystal configuration i.e. holes in slab and rods in air. It is observed from the results that a remarkable frequency shift and High quality factor of 7212 is obtained during the consideration of silicon material for accelerometer function for three different types of radius in PhC configuration. Low quality factor of 2232 is observed during the consideration of Indium Phosphate material in holes in slab configuration of photonic crystal for 0.18µm aspect ratio. This proposed work having tremendous application in inertial navigation and automobile vehicle accident detection and in airbag system.

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