International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-3, September 2019

Performance Analysis of SAW Gas Sensors with Different Number of Electrodes

Anuj Kumar Goel, B. Siva Kumar Reddy

***Abstract:** SAW technology is used to detect presence of certain molecules as used for gas sensing. Different geometries are designed with variation in number of interdigitated electrodes. Designed device used the layers of materials with variation of depth. FEM analysis is performed for two different structures. Shift in resonant frequency is observed as performance measuring parameter. Deformed shape plots are obtained with electric potential distributions for different eigenfrequencies. Different simulation results are compared to get highly sensitive device. Applications are found in many applications to sense micro, nano particles etc.*

***Keywords:** SAW Devices, Gas Sensor, Interdigitated transducer (IDT).*

I. INTRODUCTION

Surface-acoustic waves move parallel to the surface of device, with their displacement amplitude reduces into the material so that waves are limited to within approximately one wavelength of the surface [1]. These waves generates in elastic material.

SAW technology produces electric potential is generated in SAW technology by use of piezoelectric material such as gallium arsenide or quartz. This electric potential is generated due to mechanical deformation [2,3]. The electric fields do not have an effect on the circulation of the mechanical wave, so the output is a variation in electrostatic potential that circulates along with the SAW [4,5]. Any micro/nano layers of surface metal or conductive regions in the material affect the electrostatic potential variation around them, but the mechanical SAW propagation remains unchanged.

A. SAW TRANSDUCER

A SAW can be produced by applying a calculated oscillating signal to a properly modeled pair of surface gates. As shown in Fig. 1 typical SAW transducer posses of several pairs of IDT create a grating-like structure and the pitch of the transducer giving the SAW wavelength [6-8].

Manuscript published on 30 September 2019
Corresponding Author *
Anuj Kumar Goel *, Professor, Dept. of ECE, CMR Engineering College, Kandlakoya, Telangana, India-501401.
Email: anuj40b@gmail.com
B Siva Kumar Reddy, Associate Professor, Dept. of ECE, CMR Engineering College, Kandlakoya, Telangana, India-501401. Email: bsivakumar100@gmail.com

Surface Acoustic Waves can be produced if we ground one transducer's surface and by providing a frequency pointer on side divided by the pitch of the transducer. The frequency signal is calculated by SAW velocity for example 2700 meter/second for GaAs [9].

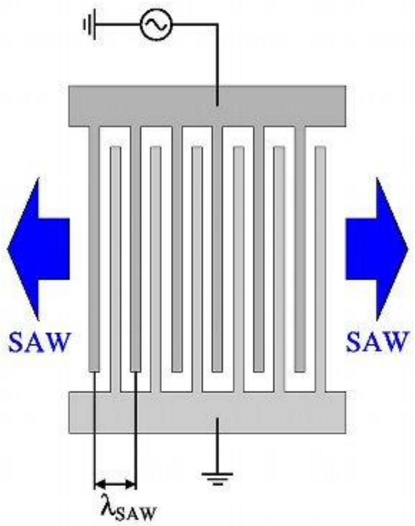

Fig.1. SAW transducer with number of Interdigitated electrodes [10].

B. SAW MATERIALS

SAW devices can be fabricated by many materials. The most commonly used single-crystal materials for our application are lithium niobate & lithium tantalate. These demonstrate various characteristics that depend on the cut of the material and the direction of propagation. Material selection is depends on many parameters such as SAW velocity, the temperature coefficients of delay (TCD), the electromechanical coupling factor and propagation loss. SAW are produced and monitored by spatially periodic, interdigitated electrodes on the plane surface of a piezoelectric plate [11].

Piezoelectric single crystals such as 128°Y-X (128°-rotated-Y-cut and X-propagation) – $LiNbO_3$ and X-112°Y (X-cut and 112°-rotated-Y-propagation) – $LiTaO_3$ are used as SAW base in Video Intermediate-Frequency (VIF) filters [12]. A *c*-axis-oriented ZnO thin film deposited on a fused quartz, glass or sapphire substrate can be used for SAW device formulation. Table I represents significant material properties regarding SAW devices [15].

Table I: SAW material properties [13-14].

	Material	Cut-propagation direction	K^2 (%)	TCD (ppm. C^{-1})	V_0 ($m.s^{-1}$)	ε_r
Single Crystal	Quartz	ST-X	0.16	0	3158	4.5
	$LiNbO_3$	128°Y-X	5.5	− 74	3960	35
	$LiTaO_3$	X112°-Y	0.75	− 18	3290	42
	$Li_2B_4O_7$	(110)-< 001 >	0.8	0	3467	9.5
Ceramic	PZT-In($Li_{3/5}W_{2/5})O_3$		1.0	10	2270	690
	(Pb,Nd)(TI,Mn,In)O_3		26	< 1	2554	225
Thin Film	ZnO / glass		0.64	− 15	3150	8.5
	ZnO / sapphire		1.0	− 30	5000	8.5

II. DESIGNED SAW DEVICE

Designed device can be used for sensing of some harmful gas molecules with change in resonance frequency. Layer by layer structure is used as lithium niobate is used as substrate material. Electrodes are fabricated over substrate by different fabrication methods as mainly used is etching. The material used for electrodes is aluminum. For detection of molecules, we should used a material that can attract respective molecules. So selection of material is main constraint of the device modeling. In this design polyisobutylene is used over the electrodes.

A. SINGLE IDT ELECTRODE

Different approaches are used to get better design of device. In first approach one electrode structure Fig. 2 is designed using one FEM modeling tool. To get best results, the design is meshed in blocks as shown in Fig. 3.

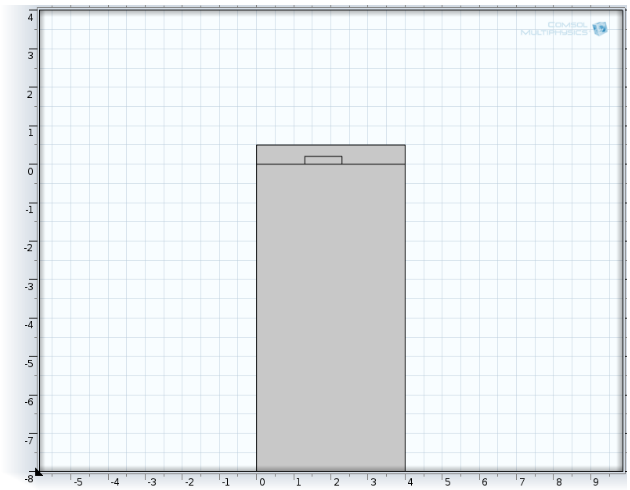

Fig. 2. Designed model with one electrode.

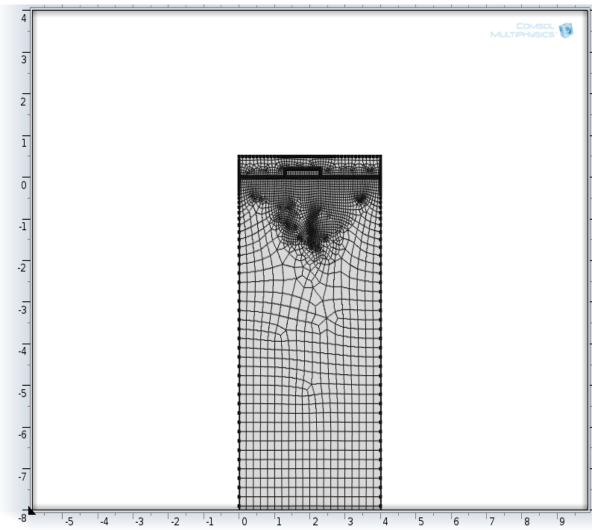

Fig. 3. Meshed designed model with one electrode.

B. DOUBLE IDT ELECTRODES

Second approach is design of two electrodes over substrate as in Fig. 4. To get best FEM result the design is meshed as shown in Fig. 5 For final design of the device geometry formation, boundary conditions, material selection etc. are most commonly used steps.

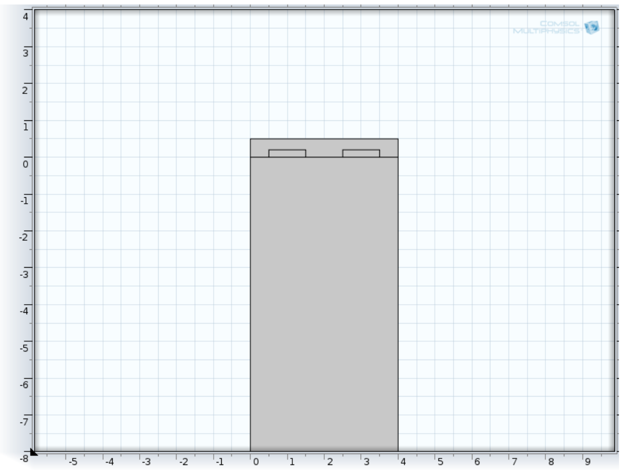

Fig. 4. Designed model with two electrodes.

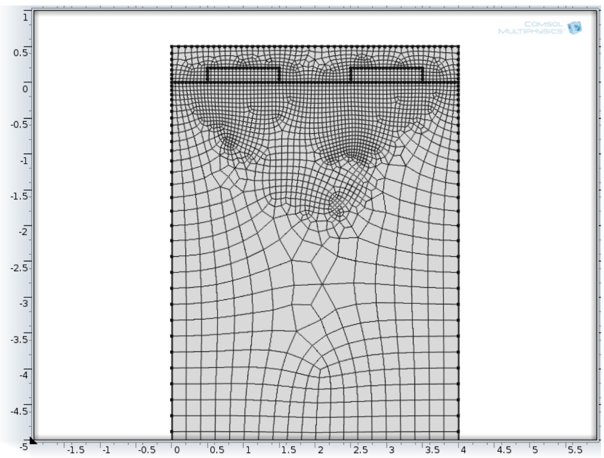

Fig. 5. Meshed designed model with two electrodes.

III. RESULTS

Designed devices are simulated with meshed structures. Fig. 6 represents the deformed shape of SAW device with eigenfrequency of 8.55e8 with maximum displacement of 1.38e-3. Fig. 7 demonstrates same device for eigenfrequency of 8.57e8 and displacement of 6.92e-4. Third result with Fig. 8 illustrates eigenfrequency of 8.38e8 with 7.69e-4 maximum displacement.

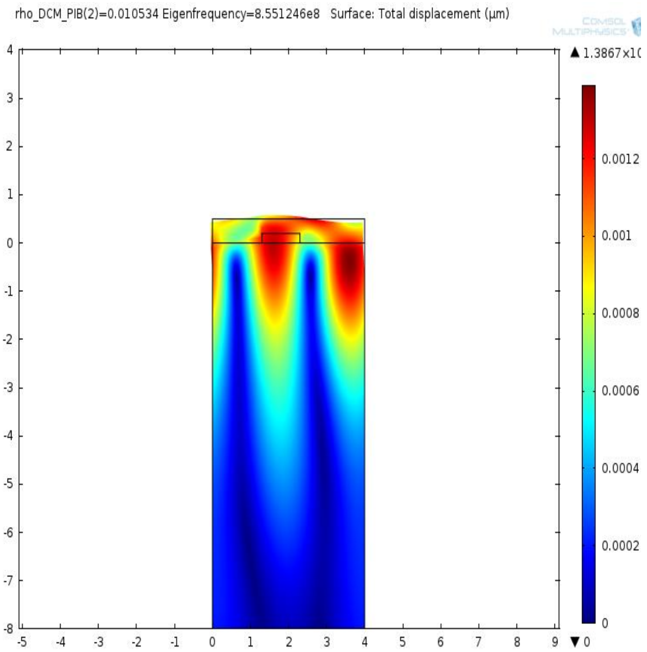

Fig. 6. SAW device 1 deformed shape 1.

Distribution of electric potentials and deformantions are visualised in Fig. 9 and Fig. 10. Variations with eigenfrequencies are shown by plot diagram in Fig. 11.

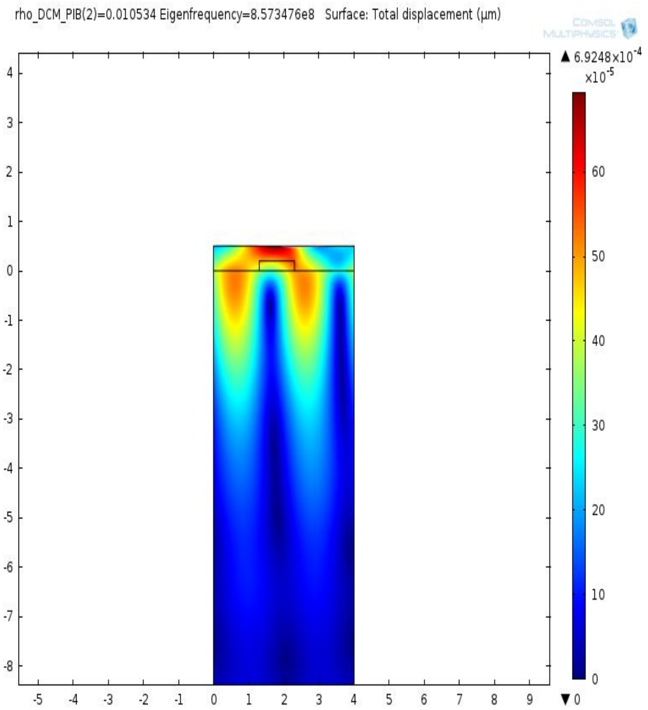

Fig. 7. SAW device 1 deformed shape 2.

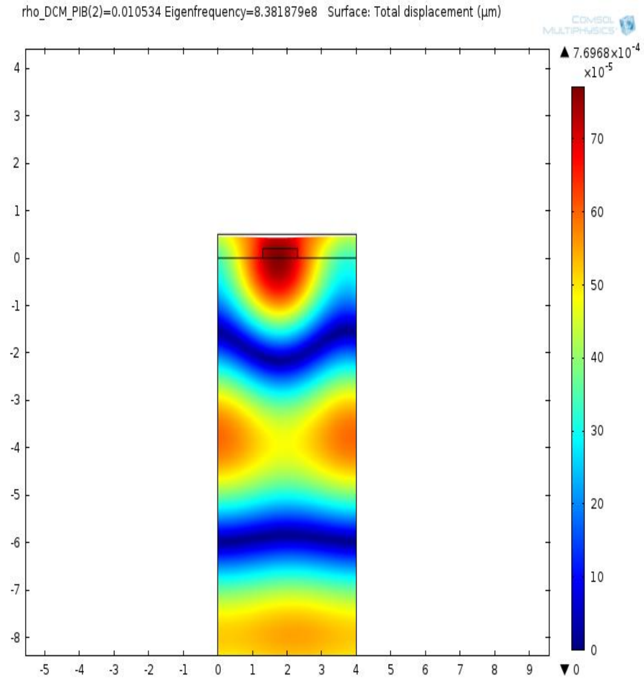

Fig. 8. SAW device 1 deformed shape 3.

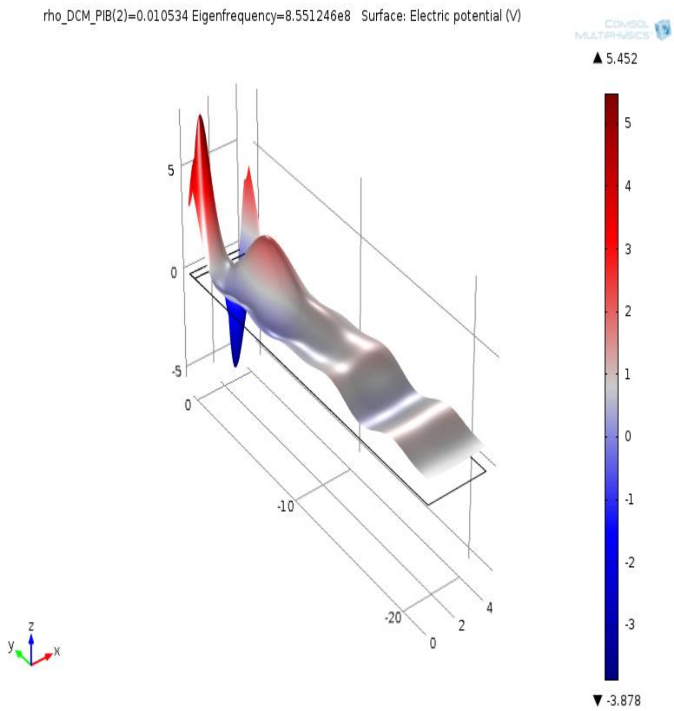

Fig. 9. SAW device 1 electric potential distribution 1.

Retrieval Number C5530098319/2019©BEIESP
DOI: 10.35940/ijrte.C5530.098319
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

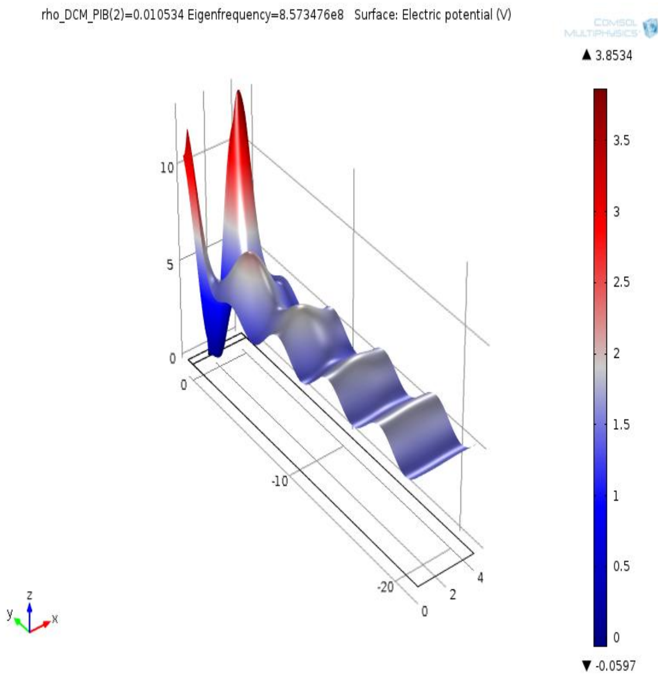

Fig. 10. SAW device 1 electric potential distribution 2.

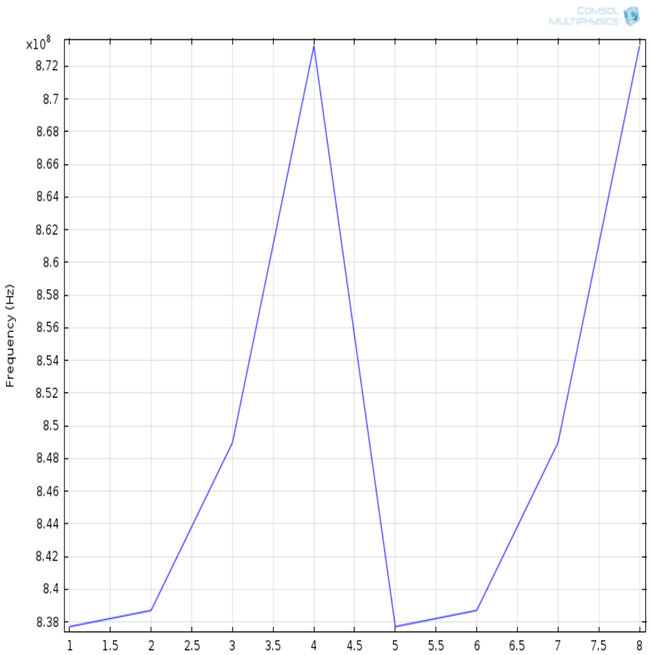

Fig. 11. SAW device 1 eigen frequency varaiation plot.

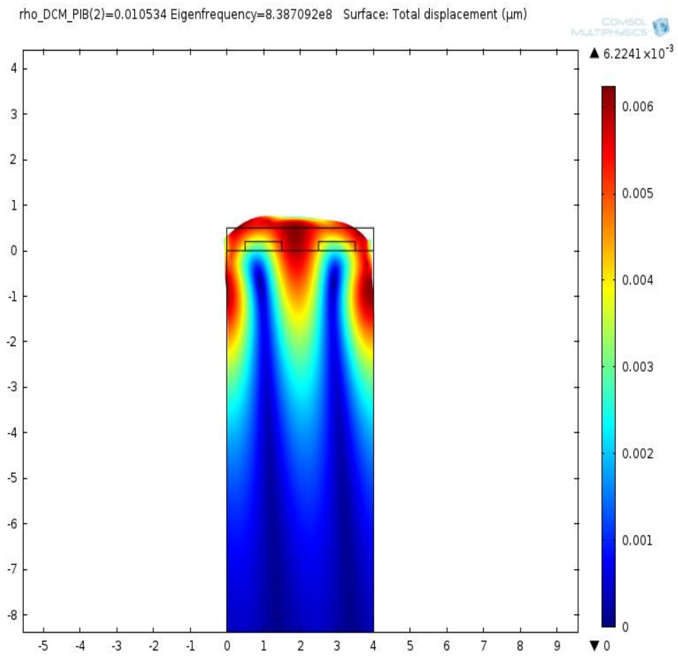

Fig. 12. SAW device 2 deformed shape 1.

The simulated structures of two electrode SAW device are shown in Fig. 12 and Fig. 13. They are achieved for different eigenfrequencies. The displaceements are also varied from 6.2e-3 to 2.0e-3. Both results are shown for change of resonance frequency and change of respective displacements. Fig. 14 shows ate electric potential distribution of SAW device 2 and that is possible due to piezoelectric material as lithium niobate.

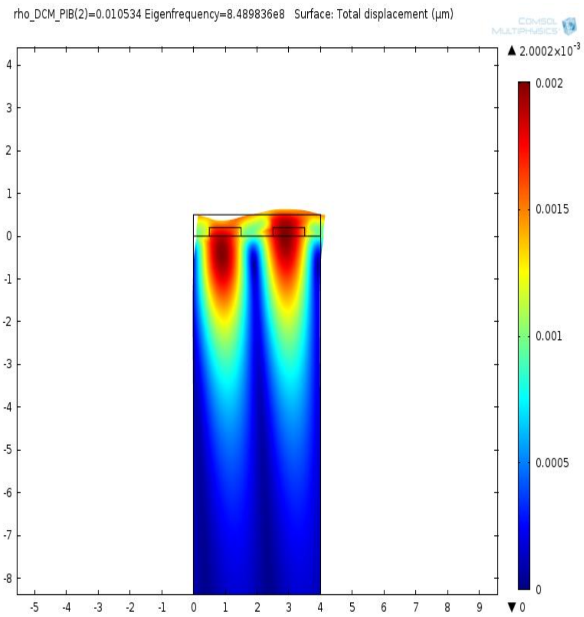

Fig. 13. SAW device 2 deformed shape 2.

Retrieval Number C5530098319/2019©BEIESP
DOI: 10.35940/ijrte.C5530.098319
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

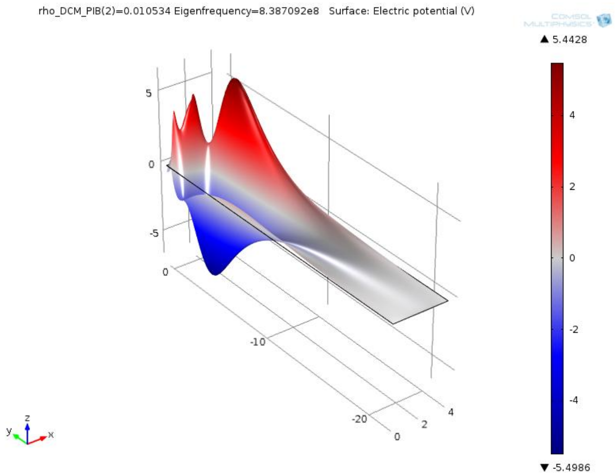

Fig. 14. SAW device 2 electric potential distribution.

Fig. 15 represents the variation of eigenfrequencies in SAW device 2 and effect of sensing material mass change.

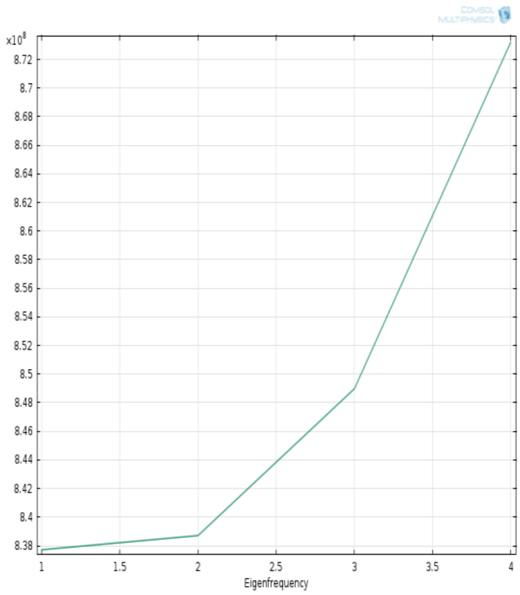

Fig. 15. SAW device 2 eigen frequency varaiation plot.

IV. CONCLUSION AND FUTURE SCOPE

SAW devices are designed to get optimum geometry. Deformed shapes, electric potential distributions explain the variations due to presence of mass change. Devices give better result for gas detection. As Future scope, Material selection of electrodes influences the device performance. The materials can be changed to achieve nano gas particles detection. Structure of electrodes can be changed to sense more effectively.

REFERENCES

1. Feng Gao, Farid Boussaid, Weipeng Xuan, Chi-Ying Tsui, Amine Bermak, Dual Transduction Surface Acoustic Wave Gas Sensor for VOC Discrimination, IEEE Electron Device Letters, Vol. 39(12) , 2018.
2. Md. Nazibul Hasan, Santanu Maity, Argha Sarkar, Chandan Tilak Bhunia, Debabrata Acharjee, Simulation and Fabrication of SAW-Based Gas Sensor with
3. Modified Surface State of Active Layer and Electrode Orientation for Enhanced H2 Gas Sensing, Journal of Electronic materials, Vol. 46(2), pp. 679-686, 2017.
4. Adnan Mujahid, Franz L. Dickert, Surface acoustic wave for chemical sensing applications of recognition layers, sensors, vol. 17, 2017.
5. Akriti Gupta, Pradeep Kumar, Sujata Pandey, Analysis of multilayered SAW based gas sensor, International Conference on Trends in Electronics and Informatics, 2017.
6. Fahim, Mainuddin, U. Mittal, Jitender Kumar1, A.T.nimal1, M.U.Sharma, Single Chip Readout Electronics for SAW Based Gas Sensor Systems, IEEE Sensors, 2017.
7. K. Ho, Eric R. Lindgren, K. Scott Rawlinson, Lucas K. McGrath, Jerome L. Wright, Development of a Surface Acoustic Wave Sensor for In-Situ Monitoring of Volatile Organic Compounds, Sensors Vol. 3, pp. 236-247, 2003.
8. S. Ahmadi , C. Korman, M. Rahaman, M. Zaghloul, Characterization of multi- and single-layer structure SAW sensor, Sensors 2004, Proceedings of IEEE, Vol. 3, pp. 1129-1132, 2004.
9. Kun Li, Xiao-Song Du, Jia Hu, Ping Sun, Ya-Dong Jiang, Optimization of the Saw Gas Sensor With Two-Port Resonantor, International Conference on Apperceiving Computing and Intelligence Analysis, 2009.
10. Mateusz Pasternak, Józef Rafa, Analytical model of SAW gas sensor with viscoelastic layer, International Conference on Sensor Technologies and Applications, 2007.
11. Anuj Kumar Goel, Kuldip Kumar, Dushyant Gupta, Design and Simulation of Microcantilevers for Sensing Applications, International Journal of Applied Engineering and Research, vol. 11(1) page 501-503, 2016.
12. Wahengbam Kanan Kumar, Anuj Goel, Design and simulation of Bulk acoustic wave MEMS resonator, IJEETE, Vol. 1(1), pp. 14-20, 2014.
13. Surface acoustic wave devices and their signal processing applications, C. Campbell, Academic press, London, 1989.
14. Surface acoustic wave devices, S. Datta, Prentice-Hall, Englewood Cliffs, New Jersey, 1986.
15. Surface wave filters: design, construction and use, edited by Matthews, John Wiley and sons, New York, 1977.
16. New advances in Material Science and Engineering Vol. 1, edited by Anuj Kumar Goel, Science Domain International, U.K., 2019.

AUTHORS PROFILE

Dr Anuj Kumar Goel is working as Professor of Electronics and Communication engineering in C.M.R. Engineering College, Hyderabad, India. He has the teaching experience of Thirteen years. He had completed his Ph.D. in MEMS Modeling from Maharishi Markandeshwar (Deemed to be University). He did M.Tech. in Microelectronics and VLSI Design from Kurukshetra University. He has published 20 papers in reputed journals(SCI, SCOPUS, Web of Science indexed etc) and 8 papers in conferences. He has been serving as an editorial board member of many international journals. He reviewed 30 research papers. He published two books on Fingerprint recognition techniques and New Advances in Material Science and Engineering, Vol. 1. He had the member ship of many professional bodies as IACSIT, IAENG, IASED, IEIECE.

Dr B. Siva Kumar Reddy, is currently working as an Associate Professor, Department of Electronics and Communication Engineering, CMR Engineering College, Hyderabad, India. He had received B.Tech (Electronics and Communication Engineering) and M.Tech (Very Large Scale Integrated Circuits Design) degrees from Jawaharlal Nehru Technological University, Hyderabad (JNTUH), PhD in the field of Wireless Communication from National Institute of Technology, Warangal, India, in 2009, 2012 and 2016, respectively. His area of research includes Multi Carrier Modulations, OFDM, internet of Things (IoT), PAPR Reduction techniques, Spectral leakages, Adaptive Modulation and Coding, Spectrum Sensing, Channel Estimation/Equalization/Synchronization, 3GPP, WiMAX, LTE, Performance analysis of sensors, Embedded sytems and Software Defined Radio. He is an ISTE (Indian Society for Technical Education) life time member and invited member of IDES (Institute of Doctors, Engineers and Scientists).