IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 10, Issue 6, Ver. II (Nov - Dec .2015), PP 01-04
www.iosrjournals.org

The Eigenfrequency Analysis of Mems Based Baw Resonator

Mude Sreenivasulu[1], Dr.Valasani Ushashree[2], Dr.P.Chandra Sekhar Reddy[3]
[1](Research Scholar,, ECE Department, JNTUH Hyderabad, India.)
[2](Professor & Dean, ECE Department, JBIET, JNTUH Hyderabad, India)
[3](Professor , ECE Department, JNTUCE, JNTUH Hyderabad, India)

Abstract: *As technology is growing very rapidly, Micro scale devices are playing a vital role in the electronic, mechanical and other application areas due to their integrability with CMOS IC technology, low power consumption, low cost Fabrication and Large frequency-Quality factor product. As there is a much demand for small and portable devices the applications of micro devices like MEMS based Bulk Acoustic Wave (BAW) resonators are rapidly increasing. In this paper we will present the analysis of thin-film BAW resonator designed in 2D using eigenfrequency by using Zinc oxide and Lead Zirconate Titanate (PZT-8) materials and try to achieve a high quality (Q) factor . The Q-factor is the most important characteristics of a resonator because it describes the frequency selectivity of the device. The high Q-factor greatly helps to implement extremely selective IF and RF filters with small percent bandwidth and low insertion loss.*

Keywords: *Bulk Acoustic Wave (BAW), Lead Zirconate and Titanate(PZT-8, Microelectromechanical systems, Quality factor, Zinc oxide(ZnO)*

I. Introduction

The MEMS are micro scaled devices that combine electrical and mechanical components. This device either can act as a sensor or as an actuator. While acting as a sensor a change in physical property creates an electrical signal and while acting as an actuator a physical effect can be created by the application of electrical signal. The MEMS devices due to their small size, low cost, low power consumption, easy integration with electronics, high resistance to vibration, low cost fabrication are very much applicable in the field of communication, automotive engineering, biomedical engineering, industrial automation, consumer electronics and etc. The MEMS resonator technology is dominating the quartz crystal technology whose main draw backs are large size, high cost and non compatibility with CMOS IC technology [1].

The on-chip integrated components like resonators and oscillators with very high quality factor are essentially needed for the upcoming communication systems. The traditional quartz crystal oscillator is usually off-chip oscillator circuit. Even though the quartz crystals are widely used in electronic systems, they are mechanical vibrating devices that give their stable natural resonance frequencies. When compared to other electronic circuits, they are large in size and very difficult to integrate on a chip. Vibrating devices like surface acoustic wave (SAW) and quartz crystal oscillators with high quality factor of the range 10^{3}-10^{6} are widely used to implement high-Q oscillator and band pass filter in the radio frequency and intermediate frequency stages of communication transceivers. As these components have very high quality factor and therefore, filters using such technologies could greatly outperform than the filters which are implemented using conventional transistor technologies in percent bandwidth, insertion loss, achievable rejection and dynamic range and etc. But, the quartz crystal and SAW devices which provide high quality factors are off-chip components that are to be interfaced with other electronic components at the board level, causing a great draw back in miniaturization of the electronic devices [2]

MEMS resonators have different shapes like circular disks, square plates, comb, annular rings, beams and etc., and can operate in the following modes namely flexural, torsional and bulk. In general, bulk mode micro resonators are preferred for high frequency generation because of its larger structural stiffness as compared to other modes. Also, bulk mode resonator yields higher Q than flexural mode resonators of the same frequency. This is because that the flexural modes have larger surface-to-volume ratios than bulk mode resonators, thus it leads to increase losses from the surface effects [3],[4].

In this paper we will present the analysis of thin-film BAW resonator designed in 2D using eigenfrequency by using Zinc oxide and Lead Zirconate Titanate (PZT-8) materials and try to achieve a high quality (Q) factor . The Q-factor is the most important characteristics of a resonator because it describes the frequency selectivity of the device. The high Q-factor greatly helps to implement extremely selective IF and RF filters with small percent bandwidth and low insertion loss. This paper emphasizes a square plate thin film resonator which is a basic element of the BAW resonator and is similar to the basic quartz resonator scaled with minimized in size.

II. Structure Of The Baw Resonator

The arbitrary scaled schematic of a BAW resonator is shown in the fig.1.The bottom layer of the resonator is silicon. The layer just above the silicon is made up of aluminium that operates as the ground electrode. The layer above the alunimiun is the active piezoelectric layer made up of Zinc oxide (ZnO).The topmost layer of the BAW resonator is aluminium electrode. As the silicon layer is etched away from the lower end of the central region of the resonator and this reduces the thickness at the central region. Because of this reason this device is called thin-film composite BAW resonator.

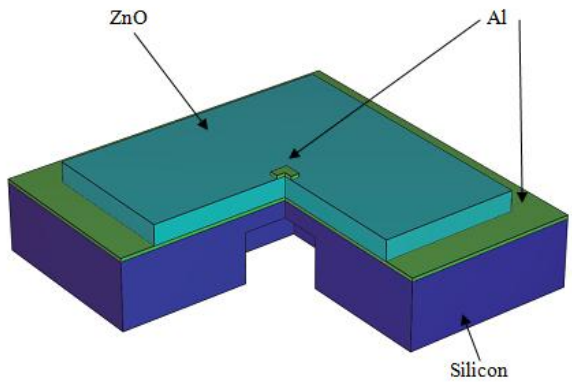
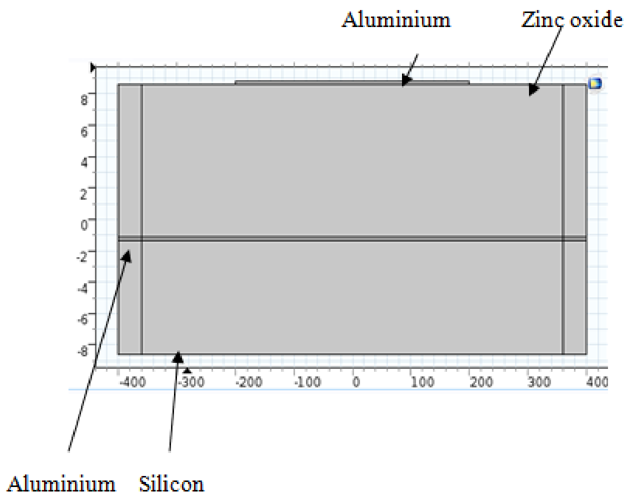


Fig (i). Arbitrarily Scaled Geometry of a BAW resonator

This model is modeled in 2D, assuming the thickness of the geometry 1.7mm, the both aluminium layers are 0.2 µm thick, the width and height of the resonator are 800 µm and 16.7 µm respectively and the length of the top electrode is 500 µm as shown in figure2. The perfectly matched layer (PML) is used on both sides of the resonator in order to reduce the anchor losses and propagation losses in the adjoining regions of the device.



III. Design And Its Operation

The design of the BAW resonator starts from defining the parameters to the modeled geometry, selection of the necessary material for each domain of the geometry and adding of the physical interfaces. During modeling of the geometry, domains must be selected in such a way that the appropriate material is inserted in the proper area and they are as follows. The complete geometry is applied with silicon material and later only the bottom layer is made to remain with silicon and linear elastic material is added to that layer. The layer above the silicon is added with aluminium (Al) which acts as a ground electrode. The layer above the aluminium is an active piezoelectric layer and is added with Zinc oxide (Zno) and Lead Zirconate and Titanate (PZT-8).After adding the corresponding material to the respective domains the next process is to apply the physics. The applied physics to the resonator are the solid mechanics and electrostatics. The materials used in the model and their properties are as given in the table (i), (ii), (iii) and (iv) are provided by the COMSOL software.

Table1: Silicon material properties

	Property	Name	Value	Unit
✓	Density	rho	2330[kg/...	kg/m³
✓	Elasticity matrix	D	{166[GPa...	Pa

Table2: Aluminum material properties

	Property	Name	Value	Unit
✓	Density	rho	2700[kg/...	kg/m³
✓	Young's modulus	E	70.0e9[Pa]	Pa
✓	Poisson's ratio	nu	0.35	1

Table3:Lead Zirconium Titanate (PZT-8) properties

	Property	Name	Value	Unit
✓	Density	rho	7600[kg/...	kg/m³
✓	Elasticity matrix (Ordering: xx,...	cE	{1.46876...	Pa
✓	Coupling matrix	eES	{0[C/m^...	C/m²
✓	Relative permittivity	epsilon...	{904.4, 9...	1

Table4: Zinc oxide material properties

	Property	Name	Value	Unit
✓	Density	rho	5680[kg/...	kg/m³
✓	Elasticity matrix (Ordering: xx,...	cE	{2.09714...	Pa
✓	Coupling matrix	eES	{0[C/m^...	C/m²
✓	Relative permittivity	epsilon...	{8.5446,...	1

A BAW resonator is an electromechanical device in which, with the application of electrical signal a standing acoustic wave is generated in the bulk of piezoelectric material. In simple words, a device consisting of piezoelectric material (Zno or PZT-8) is sandwiched between two metallic electrodes. To obtain the desired operating frequency, the natural frequency of the material and the thickness are used as design parameters. When the voltage is applied to the top electrode of the resonator, the bulk acoustic mode of the resonator is obtained from eigenfrequency analysis.

The ratio of the energy stored in the system to the energy lost per cycle is defined as the quality factor (Q).The Q-factor is the most important characteristics of a resonator because it describes the frequency selectivity of the device. The high Q-factor greatly helps to implement extremely selective IF and RF filters with small percent bandwidth and low insertion loss. The highest quality factor at high resonant frequency results in the following [1].

(I) Higher gain (II) Narrow frequency response

(III) Low energy loss per cycle and (IV) Describes frequency selectivity of the device.

IV. Results And Discussion

The BAW resonator is analyzed at several eigenfrequency values using COMSOL Multiphysics. The mode shape of the resonator which is simulated at 221.4 MHz is presented in fig.3 and the obtained Q-factor is presented in fig.4

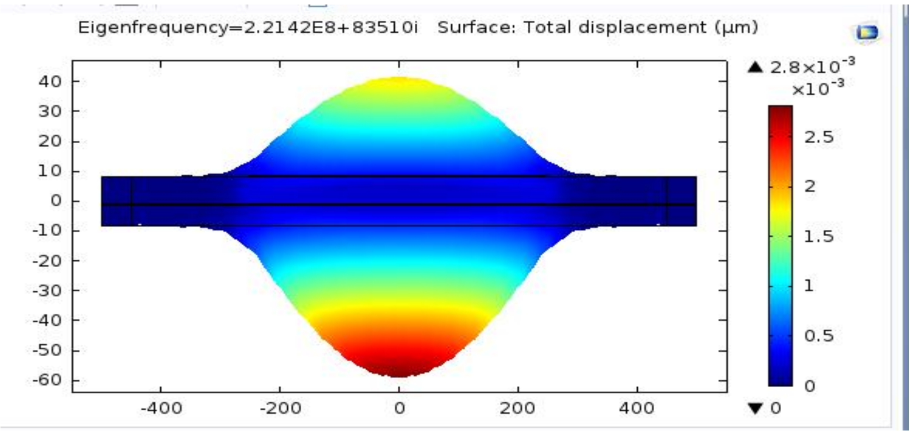


Fig 3: The bulk acoustic mode of the resonator obtained from the eigenfrequency analysis

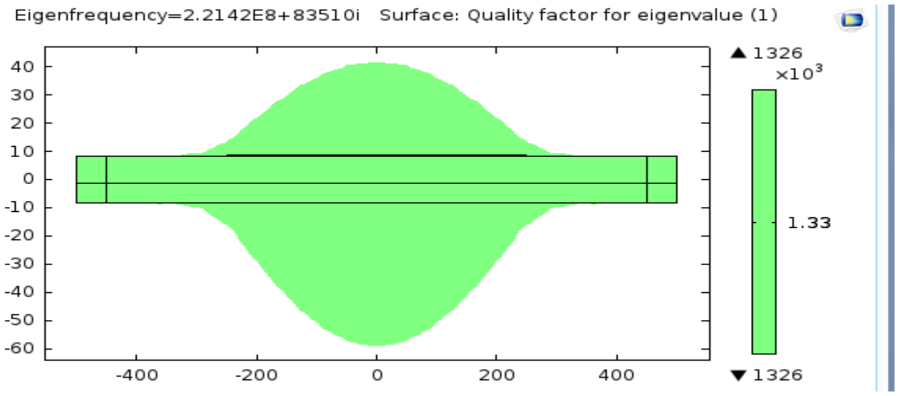


Fig 4: The Q-factor obtained at eigenfrequency of 221.4 MHz.

The BAW resonator have analyzed for two different piezoelectric materials at several eigen frequencies and their Q-factors have also been obtained as mentioned in the table below.

Table 5: Evaluated values for Zinc Oxide as a piezoelectric material

Eigenfrequency value	Measured Q-Factor
221 MHz	1326
1.2 GHz	935
1.385 GHz	2487

From the above table it is clear that for 1.385 GHz resonant frequency the obtained Q-factor is 2487 which is desired.

Table 6: Evaluated values for PZT-8 as a piezoelectric material

Eigenfrequency value	Measured Q-Factor
988 MHz	1011
1.024 GHz	1312
1.028 GHz	1481.7

V. Conclusion

From the results obtained, it is clear that the piezoelectric material Zinc oxide(ZnO) is preferable for the piezoelectric BAW resonators than the Lead Zirconate Titanate (PZT-8) which could generate high Q-factor for the highest frequency and thus these can be used for IF and RF filters with small percent bandwidth and low insertion loss.

Acknowledgement

The authors would like to thank IISc University,Bangalore for allowing to do this work and would like to extend their thanks for the people who have helped directly and indirectly.

References:

[1] Joydeep Basu and Tarun Kanti Bhattacharyya, " Microelectromechanical Resonators for Radio Frequency Communication Applications" , Microsystem Technologies, Oct 2011, vol. 17(10–11), pp. 1557–1580.
[2] Vikram Kumar Singh, Abhilash Amsanpally and Dr.K.C.James Raju , "Self Aligned MEMS Based High-Q Disk Resonator", 2012
[3] Pourkamali S, Hao Z, Ayazi F (2004) VHF single crystal silicon capacitive elliptic bulk-mode disk resonators–part II: implementation and characterization. J Microelectromech Syst 13(6):1054–1062.
[4] Lee JEY, Seshia AA (2009) 5.4-MHz single-crystal silicon wine glass mode disk resonator with quality factor of 2 million. Sens Actuators A 156:28–35.
[5] R. Clark, W.-T. Hsu and C. T.-C. Nguyen, "High-Q VHF Micromechanical Contour-mode Disk Resonator," Technical Digest, IEEE Int. Electron Devices Meeting, San Francisco, California, Dec. I 1-13, 2000, pp. 493-496.
[6] High-Q HF Micro electromechanical Filters, Frank D. Bann on, III, Student Member, IEEE, John R. Clark, Student Member, IEEE and Clark T.-C. Nguyen, Member, IEEE JOURNAL OF SOLID-STATE CIRCUITS, VOL. 35, NO. 4, APRIL 2000.