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Performance Comparison of Surface Acoustic Wave Resonators and Bulk Acoustic Wave Resonators

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Abstract- In this paper performance of Surface Acoustic Wave resonators and Bulk Acoustic Wave resonators are analyzed. Quality factor analysis and power dissipation analysis are done by using Lithium Niobate as piezoelectric layer. The maximum value of Quality factor value and minimum value of power dissipation is obtained in Bulk Acoustic Wave resonators. Both the analysis are performed by using COMSOL Multiphysics Software.

Index Terms- Surface Acoustic Wave resonator, Bulk Acoustic Wave resonator, Power dissipation, Quality Factor, Eigen frequency

1. INTRODUCTION

Nowadays we are facing the challenge of developing low cost and low loss passive components for microwave and radio frequency applications [1]. These low loss resonators and filters would improve the conception of active devices, and seek to reduce interconnection and packaging problems. Passive elements are critical for wireless applications. High quality factor (Q), low loss, low cost and high performance RF passive components, such as resonators, filters and transmission lines are necessary as they need to be integrated with existing active components. The unloaded quality factor establishes an upper limit for the resonator performance. An accurate measurement of the unloaded Q-factor of a microwave resonator is of prime importance. Although the unloaded Q may be calculated theoretically, it cannot be directly measured in practice.

2. BULK ACOUSTIC WAVE RESONATORS

A Bulk Acoustic Wave (BAW) device is formed by a thin film of piezoelectric material, which deforms in response to a transverse electric field. The resonant frequency of a BAW device is set by the thickness (or thinness) of the resonant layer, which yields the highest attainable frequency of the acoustic resonator categories.

2.1. *Thin Film Bulk Acoustic Wave Resonators*

Thin Film Bulk Acoustic Resonator (FBAR or TFBAR) [2] is a device consisting of a piezoelectric material sandwiched between two electrodes and acoustically isolated from the surrounding medium with thickness ranging from several micrometres down to tenth of micrometres resonating in the frequency range of roughly 100 MHz to 10 GHz. In the wireless telecommunication world, film bulk acoustic wave resonators [3] are very promising for use as RF MEMS filters since they can be combined to make up duplexers (transmitter/receiver modules). Fig.1 shows geometry of the modeled resonator. The lowest layer of the resonator is silicon substrate on top of which is the aluminum layer that operates as the ground electrode. A piezoelectric layer made of Lithium Niobate material is laid over the ground electrode and above this piezoelectric layer is the metal electrode. The Perfectly Matched Layer (PML) effectively simulates the effect of propagation and absorption of elastic waves in the adjoining regions.

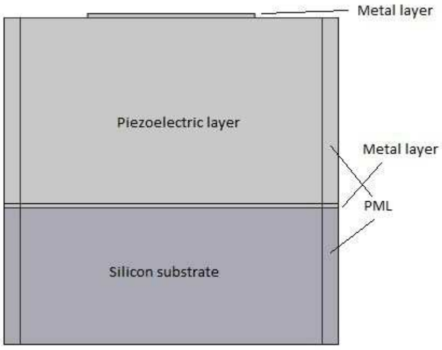

Fig. 1.Geometry of a Bulk acoustic wave resonator

The resonator dimensions used for simulating the resonator are shown in Table 1.

TABLE I: RESONATOR DIMENSIONS

Parameters	Thickness	Width
Silicon layers	7µm	1.7mm

Metal layers (Aluminium)	top	0.2µm	500µm
	middle	0.2µm	1.7mm
Piezoelectric layer (Lithium Niobate)		9.5µm	1.7mm

2.2 Surface Acoustic Wave Resonators

A Surface Acoustic Wave (SAW) resonator is also formed from a piezoelectric layer, and acoustic waves travel along the surface of the material. Typically, these propagate as Rayleigh waves, which comprise particle displacement normal to the piezoelectric surface and have a finite penetration depth within the layer [4]. They are said to be 'launched' from a set of interdigitated electrodes whose spacing determines the wavelength of the surface acoustic wave, and they can be received by a second set of electrodes to form a delay line [5] or reflected from a second set of electrodes to form a resonant cavity on the substrate surface [6].

Fig.2 shows the basic structure of a SAW resonator [4]. SAW resonator, showing the IDT electrodes (in black), the thin PIB film (light gray), and the LiNbO_3 substrate (dark gray). A 500 nm PIB film covers two 1 µm-wide electrodes on top of the LiNbO3 substrate. The substrate domain has a total height of 12 µm. A high-Q resonator can be realized by generating a standing wave between comb electrodes and increasing the number of electrode teeth.

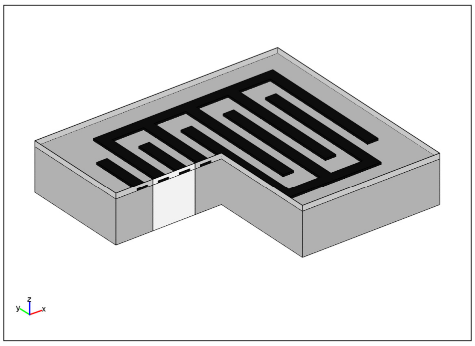

Fig. 2. Geometry of a Surface Acoustic Wave Resonator

3. SIMULATION RESULTS

Quality Factor (Q) is one of the most important characteristics of MEMS resonators, especially for vibrating structures where the resonant frequency variation is monitored. Higher the Quality Factor value better the resonator performance. Signal to noise ratio increases and power dissipation decreases. High Quality factor circuits can be used for various wireless applications. Quality factor value is a dimensionless parameter.

Table II shows the Quality factor value obtained at different eigen frequencies in GHz range in case of Bulk Acoustic Wave resonators.

TABLE II: EIGEN FREQUENCY VS QUALITY FACTOR ANALYSIS OF BULK ACOUSTIC WAVE RESONATOR

Eigen Frequency(GHz)	Quality factor
5.05461	11457.06223
5.05462	11545.01821
5.05463	11540.50889
5.05463	11360.28538
5.05463	11527.82579
5.05464	11402.72744
5.05464	11523.95302
5.05465	11473.03415
5.05466	11504.00625
5.05467	11530.47881
5.05469	11505.42211
5.0547	11526.38412

Table III shows the Quality factor value obtained at different eigen frequencies in GHz range in case of Surface Acoustic Wave resonators.

TABLE III: EIGEN FREQUENCY VS QUALITY FACTOR ANALYSIS OF SURFACE ACOUSTIC WAVE RESONATOR

Eigen Frequency(GHz)	Quality factor
4.81095	1110.74005
4.82758	1067.58929
4.84145	1235.27104
4.90101	1262.32194
4.92612	1734.33749
4.96331	1133.48563
5.02292	1224.59831
5.04436	1017.64303
5.07544	1075.47135
5.11033	1055.04155
5.15517	1176.21064
5.19128	1625.42762

The graphical representation of Quality factor analysis for both Bulk Acoustic Wave resonators and Surface Acoustic Wave resonators are shown in Fig.3.

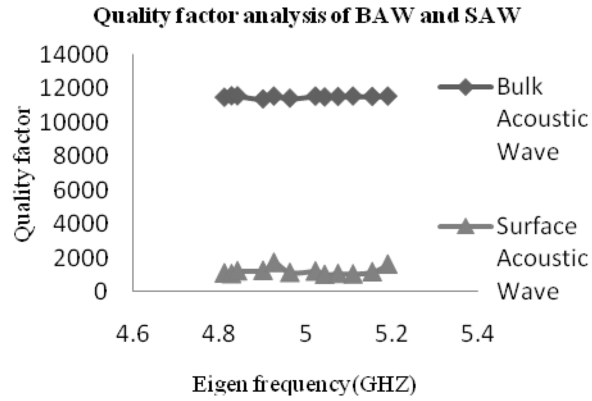

Fig. 3.Quality factor analysis of BAW and SAW resonators

Table IV shows the power dissipation values obtained at different eigen frequencies in GHz range in case of Bulk Acoustic Wave resonators. From Table 3 it is clear that minimum value of power dissipation is 1.37919 at a frequency of 4.9GHz.

TABLE IV: EIGEN FREQUENCY VS POWER ANALYSIS OF BULK ACOUSTIC WAVE RESONATOR

Eigen Frequency(GHz)	Power Dissipation (Watt)
4.81095	2.24304
4.82758	4.40109
4.84145	4.15173
4.90101	1.37919
4.92612	3.60501
4.96331	1.64329
5.02292	3.44021
5.04436	2.34641
5.07544	2.88407
5.11033	3.52413
5.15517	2.83866
5.15518	3.31096

Table V shows the Quality factor value obtained at different eigen frequencies in GHz range in case of Surface Acoustic Wave resonators. From Table IV it is clear that minimum value of power dissipation is 140.4 at a frequency of 5.11 GHz. By analyzing both Table III and Table IV ,minimum value of power dissipation is obtained by using Bulk Acoustic Wave resonators.

TABLE V: EIGEN FREQUENCY VS POWER DISSIPATION OF SURFACE ACOUSTIC WAVE RESONATOR

Eigen Frequency(GHz)	Power Dissipation (Watt)
4.81095	74.29935
4.82758	45.63944
4.84145	217.6779
4.90101	109.16314
4.92612	83.64387
4.96331	33.84332
5.02292	120.77483
5.04436	117.9037
5.07544	48.88455
5.11033	140.41326
5.15517	42.63999
5.15518	76.70724

The graphical representation of power dissipation for both Bulk Acoustic Wave resonators and Surface Acoustic Wave resonators are shown in Fig.4 and Fig.5.

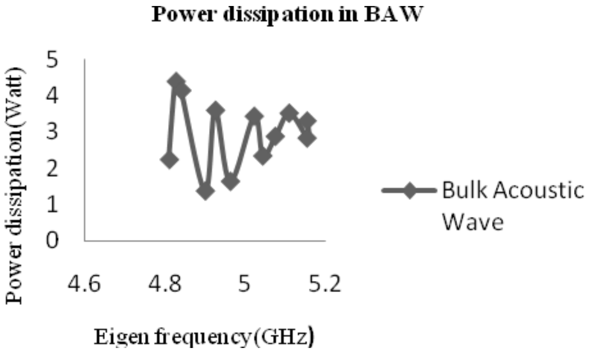

Fig. 4. Power dissipation analysis of Bulk Acoustic Wave Resonator

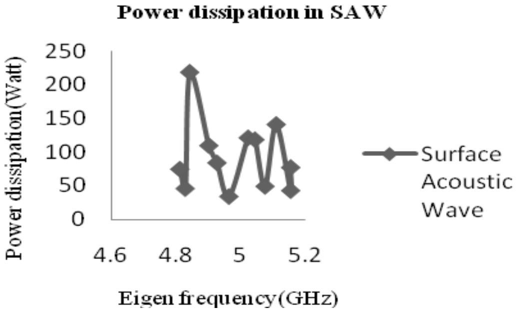

Fig. 5.Power dissipation analysis of Surface Acoustic Wave Resonator

Eigen frequency analysis is used to find out Quality factor and the dissipated power. All the design and modeling are done using COMSOL Multiphysics software. The Eigen frequency analysis plot shown in Fig.6 and Fig.7 explains the lowest BAW mode and lowest SAW mode of the structure respectively.

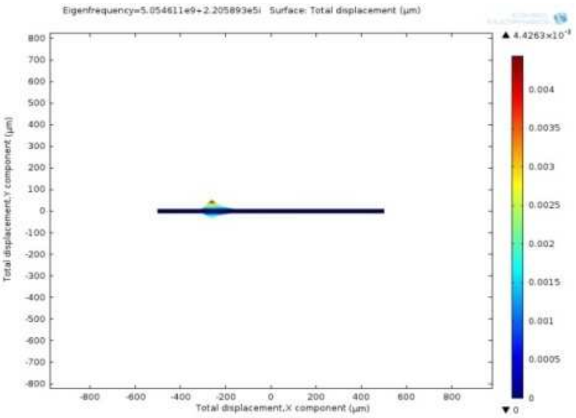

Fig. 6.The lowest bulk acoustic mode of the resonator identified from the solutions of the Eigen frequency analysis.

The eigen frequency values are shown in results as complex numbers wherein the real part provides the actual displacement frequency while the imaginary part is an indication of the extent of damping. The Eigen frequency analysis plot shown in Fig.6 explains the lowest SAW mode of the structure.

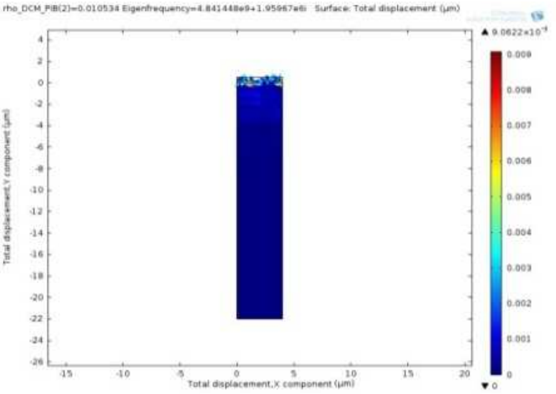

Fig. 7.The lowest surface acoustic mode of the resonator identified from the solutions of the Eigen frequency analysis

4. CONCLUSION

Performance of Surface Acoustic Wave resonators and Bulk Acoustic Wave resonators are analyzed. Quality factor analysis and power dissipation analysis are done by using Lithium Niobate as piezoelectric layer. The maximum value of Quality factor value and minimum value of power dissipation is obtained in Bulk Acoustic Wave resonators. Thus comparing BAW and SAW resonators, BAW possess better performance than SAW resonators. Both the analysis are performed by using COMSOL Multiphysics Software.

REFERENCES

[1]Gabriel.M.Rebeiz, RF MEMS Theory, Design and Technology,2003

[2] Sneha Dixit,” Film Bulk Acoustic Wave (FBAR) Resonator”, in Scientific and Research Publications,Vol.5Iss.2, 2015

[3] Tapani Makkonen, Antti Holappa, Juha Ella, and Martti M. Salomaa,“Finite element simulations of Thin-Film Composite BAW Resonators,” *IEEE Trans. On Ultrason, Ferroelectrics, and Frequency Cotrol*, VOL. 48, no5,pp.1241-1258, 2001

[4] H. Campanella, Acoustic wave and electromechanical resonators. Artech House Publishers, Feb. 2010.

[5] W. Buff, “SAW sensors,” Sensors & Actuators: A. Physical, vol. 30, no. 1-2, pp. 117–121, Jan. 1992.

[6] E. J. Staples, J. S. Schoenwald, R. C. Rosenfeld, and C. S. Hartmann, “1974 Ultrasonics Symposium,” in 1974 Ultrasonics Symposium. IEEE, 1974, pp. 245–252.