Film Bulk Acoustic Wave (FBAR) Resonator

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Abstract- In recent years, there has been an exponential growth in wireless communication systems. This is basically due to the manufacture of small size and high performance devices. Many communication devices such as filter, duplexer and oscillator require resonator as a key component. Acoustic resonators have become a key technology of growing wireless field as the propagation velocity of acoustic wave is almost five times lower than the electromagnetic waves thus resulting in small size devices. BAW resonator can be used as narrow band filter in radio-frequency applications.

Index Terms- BAW Resonator, BVD, Parameter of Interest

I. Introduction

The growing use of mobile communication systems that operate at radio frequencies (RF) of call for ever smaller, better and cheaper bandpass filters. These bandpass filters are required to transmit or receive signals within a certain bandwidth at a specified frequency and suppress all other signals. Global positioning systems (GPS, Galileo), mobile telecommunication systems (GSM, PCS, UMTS), data transfer (Bluetooth, Wireless Local Area Network WLAN), satellite broadcasting and future traffic control communication are examples of such applications.

Bandpass filters for RF signal treatment are today fabricated using different technologies:

i)ceramic filters based on dielectric resonators, ii) filters using Surface Acoustic Wave (SAW) resonators, and iii) filters using thin film Bulk Acoustic Wave (BAW) resonators.

The Bulk Acoustic Wave (BAW) resonators and filters operating in the GHz range are used in mobile phone for the filtering purpose. BAW resonators can be used as narrow band filters in RF/Microwave applications. Their advantages are small size, monolithic implementation allowing large scale integration of MMIC devices, high mechanical quality (Q) performance, and large power handling capabilities, series and parallel resonance usable for bandpass filters, compatible with standard IC technology and low cost.

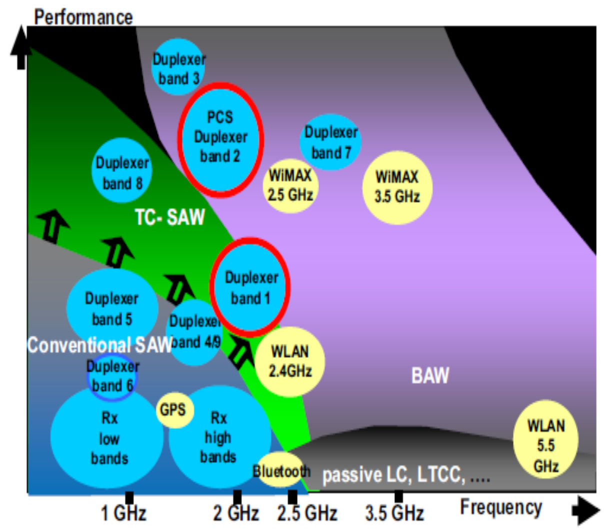

Fig.1: Mobile commercial applications mapped to current RF filter technologies, performance and frequencies

II. BAW Resonator

BAW device has acoustic wave propagation (acoustic wave that propagates though the substrate) in the piezoelectric material between the top and the bottom electrode. It is a piezoelectric device, means that the piezoelectric effect brings the electromechanical conversion.

The BAW resonator is the core element of the BAW technology. The basic Baw resonator is composed of a piezoelectric plate sandwiched between metallic electrodes and having reflecting boundaries to confine the acoustic wave. In simple way to understand we can take it like this that the resonator is in the form of a simple capacitor. When an alternating electric potential is applied to a piezoelectric material, it produces mechanical deformation. The FBAR act as an acoustic cavity resonator in which the acoustic wave bouncing back and forward between walls $\lambda/2$ apart upon proper excitation. The electrodes (Al, Au etc.) act as acoustic impedance discontinuities and the medium filling the cavity is a piezoelectric material (ZnO, AIN etc.). The electrical impedance response of FBAR has two resonant frequencies i.e. series resonant frequency where impedance is minimum and parallel resonant frequency where impedance is maximum

The main mode of operation of BAW resonator is the thickness or longitudinal mode, meaning that the bulk acoustic wave reflects the large plate surface and the resonance caused by the wave excited to the thickness direction.

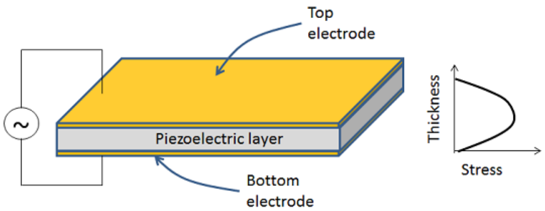

Fig.2 Excitation of BAW Resonator

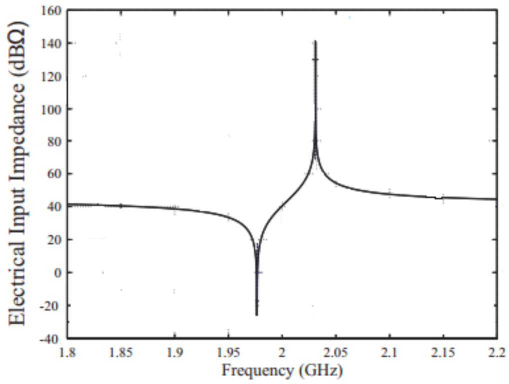

Fig.3 Ideal electrical input impedance

The performance of a film bulk acoustic wave resonator (FBAR) is analysed by the impedance characteristics of the resonator. The impedance of a resonator is characteristics of the resonator. The impedance of a resonator is characterized by two resonances: first at the resonance frequency (f_r) where the magnitude of the impedance tends to its minimum value and the second at anti – resonance frequency (f_a) where the magnitude of the impedance is maximum. The fundamental resonance frequency F of the thickness excited FBAR is given by:

$$F = \frac{v}{\lambda} = \frac{v}{2t}$$

Where, v is the velocity of fundamental thickness, λ is the acoustic wavelength and λ = 2t, t is the thickness of the device.

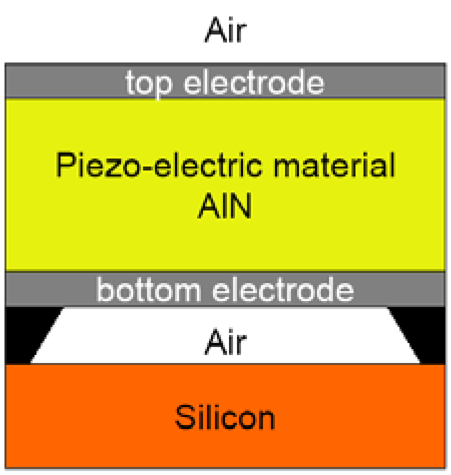

Fig4 Schematic view of bulk acoustic wave resonator FBAR

The relationship between acoustic impedance, acoustic velocity and thickness of electrode and piezoelectric material is given by:

$$Z_e / Z_p = \tan \theta_e . \tan \theta_p$$

Where, Z_e and Z_p are the acoustic impedance of electrical and piezoelectric material. The FBAR has air interface at top and bottom electrode for acoustic isolation the air cavity is created by micromachining. The resonance frequency of the lateral mode is approximated by:

$$F = N (v_L / 2w)$$

Where, N is the mode number, v_L is the velocity of the lateral mode, w is the distance between electrode edges

III. Butterworth-Van Dyke (BVD)

The equivalent circuit model of the BAW resonator is the Butterworth-Van-Dyke (BVD) model. It has two parallel branches- namely, the motional and static capacitance arms. The motional arm comprises the series motional inductance Lm, capacitance Cm, and resistance Rm. The static branch is formed by the parallel- plate capacitance Co formed between the top and bottom electrodes of FBAR

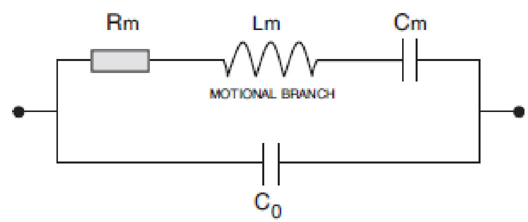

Fig.5 Equivalent Circuit

As the BVD explains the series and parallel resonance frequencies found in FBAR MEMS resonator, given by:

$$f_s = \frac{1}{2\pi(\sqrt{Lm\ Cm})}$$

$$f_p = \frac{1}{2\pi\sqrt{Lm.(\frac{Cm.Co}{Cm+Co})}}$$

IV. Parameter Of Interest

The two parameter of interest are as follows:

- Electromechanical Coupling Coefficient, K^2_{eff}

It is a important parameter for the design of BAW filter because the width of the filter passband that can be achieved depends on it.

$$K^2_{eff} = \frac{\pi}{2} \frac{fr}{fa} \cot\left(\frac{\pi}{2} . \frac{fs}{fp}\right)$$

- Quality Factor

The Quality factor is a measure of the loss of a resonator circuit and is defined as the ratio of the stored energy divided by the power dissipated in that network over one cycle.

$$Q = f_r / \Delta f_{3dB}$$

Where, f_r the resonance frequency and the other one is the bandwidth

V. Conclusion

The FBAR are highly useful for the design of low cost, small size and high performance filter, duplexers and oscillators for wireless systems

Acknowledgement

Author is thankful to Prof. R.C Jain, HOD, JIIT, NOIDA for his support and guidance.

References

[1] Mahon S, Aigner R. Bulk acoustic wave devices–why, how, and where they are going. In CS MANTECH conference, pp. 15-18, Austin, Texas, USA, 2007

[2] CAMPANELLA ,H. Acoustic Wave and Electromechanical resonators: concept to key Applications .Norwood: Artech House, 2010

[3] K. Y Hashimoto editor, RF Bulk Acoustic wave Filters for communications, Norwood: Artech House, 2009

[4] K.M. Lakin, "Thin Film Resonators and Filters," 1999 IEEE Ultrasonics Symposium Proc., pp.895-906.

[5] J. Rosenbaum, Bulk Acoustic Wave Theory and Devices. Artech House, 1988.

[6] M. Ylilammi, "Handbook of Bulk Acoustic Wave Resonators and Filters," 2000, VTT Internal report.

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