A Study on Baw Technology: Reconfiguration of FBAR Filter

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Abstract---This paper presents the importance of RF filter technology i.e. BAW technology based filter in the mobile communication. FBAR Filters have the characteristic of high power handling, a low volume, high Quality factors, good thermal stability, a low cost and compatible with IC chip integration. FBAR filter technology applications increases in RF systems because of these networks like Wi-Fi, CDMA etc. we need a switchable FBAR filter in order to incorporate all functions related to these network in a single device.
Keywords: FBAR filter, switchable filter, resonance frequency.

I. INTRODUCTION

From the last 10-15 years, the RF filter technology based on MEMS devices becomes a viable alternative with superior RF performance over traditional semiconductor switches, such as diodes and FET transistors. RF filters used in the next generation of broadband, wireless, and intelligent communication and radar systems. For the next generation of wireless communication high performance radio frequency (RF) band pass filter and high quality oscillator will be needed. Wireless communication devices require integrated functions and reduced size and cost like multi-standard wireless handset which operate with current and future cellular networks as well as GPS, Wi-Fi, CDMA and even satellite phone network. In order to integrate all of these functions related to these networks in a one system, It is necessitate to have a filter which has the characteristic of switch to select the frequency band of interest for a given application [1]. And the filter are used at microwave frequencies have small size.

The RF filters are based on dielectric resonators like surface acoustic wave (SAW) technology. SAW filters have the characteristics of good selectivity But the use of these filters are limited in frequency below 3GHz range and cannot handle high power levels [2]. Bulk Acoustic Wave (BAW) technology has replaced the SAW technology. Bulk acoustic wave (BAW) devices are the good devices for applications at higher microwave frequencies above 2 GHz. There are applications in RF instrumentation, optical networks sensors, radar systems, and. There are also those wireless applications under which a variety of frequency bands equal and above 2 GHz such as the ISM bands at 2.4 GHz and 5.7 GHz [3]. Bulk Acoustic Wave (BAW) is the acoustic wave that propagation in the bulk of material of infinite dimension and where in the wave covers all of that volume . Film Bulk acoustic resonator filtering technology have small dimensions, as the acoustic wave are shorter than electromagnetic wave. Film Bulk acoustic resonator filtering technology can handle high power levels and also have high Quality factor(Q-factor) is compatible with standard IC technology and this makes the whole system integration on a single chip and at very competitive cost [4].

II. BASIC OF FBAR

A. *Principle of FBAR*

BAW technology is based on the piezoelectric effect according to which generation of a mechanical resonance from an electrical input or vice versa. Fig 1 shows a resonator consisting of piezoelectric plate of thickness t sandwiched by infinitely thin electrodes. so if we take t=100 micrometer then the resonance frequency is 30 mega Hz .but if we take AlN resonator operating at 2GHz we arrive plate thickness of roughly 3 micrometer. this is the basic system where thin film technology enters the picture[5].

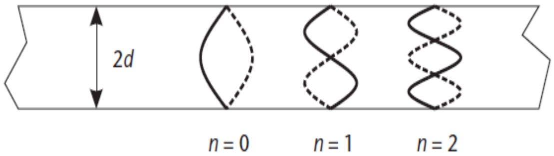

Fig. 1: Mechanical Resonance in a Plate of Thickness t

Due to an increased demand for higher frequencies the fabrication of the BAW resonators has regularly increased. use of single crystals for high frequencies application is not technologically possible because the resonance frequency depends on the thickness of the substrate and the substrate thickness cannot be thinned below a certain value of thickness without any involuntary damages [6] and Thin film bulk acoustic wave resonators consist of a piezoelectric transducer, and sandwiched between two parallel metal plates, and the energy is confined within the resonator as shown in Fig 2.

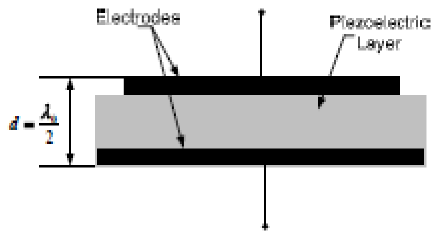

Fig. 2: FBAR Basic Structure.

When an electric field is created between these electrodes, the structure is [7] mechanically deformed by the way of inverse piezoelectric effect and an acoustic wave is generated into the resonator which propagates parallel to the electric field and acoustic wave is reflected at the electrode air interfaces. At the mechanical resonance, the half wavelength of the acoustic wave is equal to the total thickness of the stack. The resonance frequency f_r is estimated by the thickness *t* of the piezoelectric film :

$$f_r \approx \frac{v}{\lambda} = \frac{v_l}{2t} \quad (2.1)$$

Where v*l* is the longitudinal acoustic velocity in the normal direction in the piezoelectric layer, *t* is the thickness of the piezoelectric film, and λ is the acoustic wavelength. In a practical resonator device, the resonance frequency is different from (2.1), since the acoustic properties of all other layers influence the resonator performance e.g. by the mass-loading effect of the resonator's electrodes. Albeit equation (2.1) is only a crude approximation it is important to note that as the velocity of sound is typically in the range between 3000–11000 m/s for most of the materials, which is smaller than electromagnetic wave velocity so the desired thickness of the piezo layer is in the order of micrometers which makes the devices size relatively small. For the device to be practical, there are two as shown in Fig 3 in both these type of FBAR energy is confined between two parallel plates.

B. FBAR Impedance characteristics

The impedance behavior of FBAR is explained by dissimilar layer's thickness that compose of the FBAR and this characteristic helps to reconfigure the FBAR filter and due to piezoelectric effect the piezoelectric material get deformed and this piezoelectric effect is possible only in crystals having symmetrical charge distributions so that lattice deformation occur due

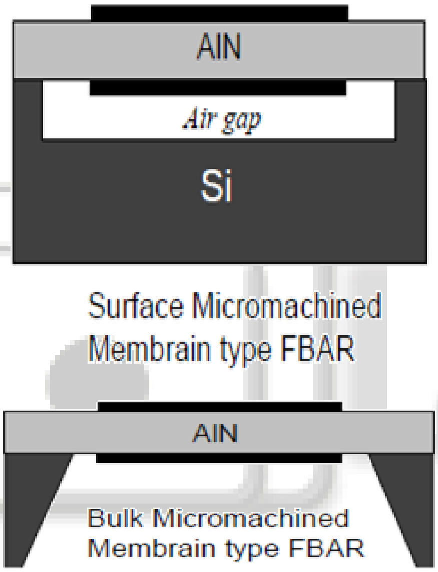

Fig. 3: FBAR

to relative displacement of positive and negative charges within the lattice. so this deformation changes the dimension of the piezoelectric material which affect the filter response. Fig 2 is basic structure of FBAR and Fig 4 shows the impedance characteristic of FBAR.

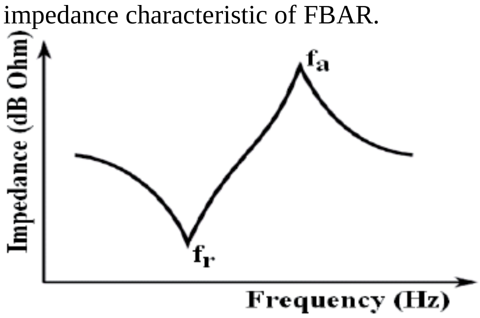

Fig. 4: electrical input impedance response of FBAR.

The FBAR illustrate two points of resonance: the series resonance (fs), when the electrical impedance approaches to zero, and the parallel resonance (fa), when the electrical impedance approaches to infinity and for all other frequencies which are different from resonance frequency FBAR shows the static capacitance response. The difference between the series resonance frequency and parallel resonance frequency is estimated from the effective electromechanical coupling coefficient of piezoelectric material..

C. Circuit Configuration of FBAR

The FBAR has an equivalent circuit is Butterworth Van Dyke circuit model consists of two parallel branches—namely, the motional arm and the static capacitance arm. The motional arm comprises the series motional inductance L_m, capacitance C_m, and resistance R_m. The static capacitance branch is shown by the capacitance C_0 as shown in Fig 5

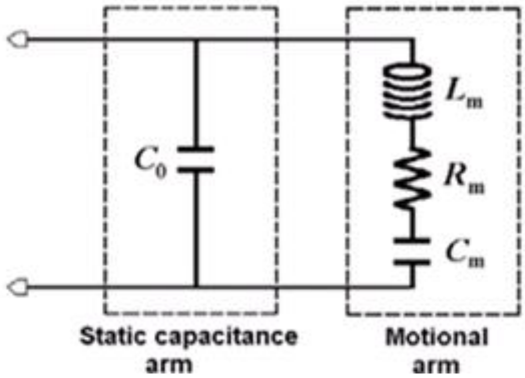

Fig. 5: Equivalent BVD circuit of FBAR resonator

FBAR modified Butterworth-Van-Dyke model known as MBVD, as shown in Fig 1.6. C0 is the physical plate capacitance of the FBAR and Rs is the electrode's physical resistance Cm, Lm, and Rm is the motional resonance that is coupled to the voltage across the plate capacitor by the piezoelectric effect in the piezoelectric material. R0 is the dielectric loss tangent of piezoelectric material and models most of the losses associated with the parasitic lateral model in the FBAR [8].

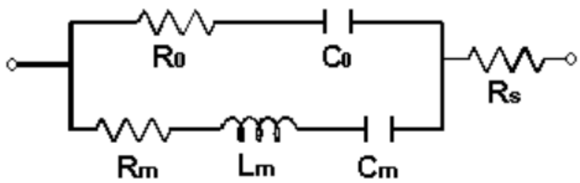

Fig. 6: Equivalent MBVD circuit of FBAR resonator

$$f_s = \frac{1}{2\pi}\sqrt{\frac{1}{L_m C_m}} \qquad (2.2)$$

$$f_p = \frac{1}{2\pi}\sqrt{\frac{1}{L_m C_m}\left(1+\frac{C_m}{C_o}\right)} \qquad (2.3)$$

Where fs is series resonance frequency and fp is parallel resonance frequency[9].

III. SWITCHABLE FBAR

Resonance frequency of the FBAR is varying with the thickness of the electrode. So as the thickness of electrode is increases by addition of the layer then the resonance frequency is decreases ,that's why FBAR filter can be used as switch which resonate at different frequency corresponding to different electrode thickness [7].

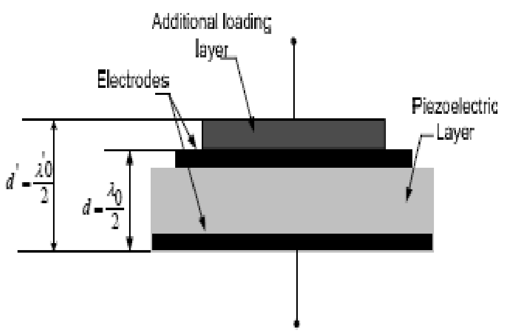

Fig. 7: FBAR with Additional Loading Layer

The electrical impedance of an FBAR is obtained by solving the acoustic boundary problem and applying the transmission line theory [6]. The electrical FBAR impedance can be simplified and expressed by the following equation (2.4) :

$$Z_{FBAR} = \frac{1}{j\omega c_0} \frac{(\omega^2 - \omega_s^2)}{(\omega^2 - \omega_p^2)} \quad (2.4)$$

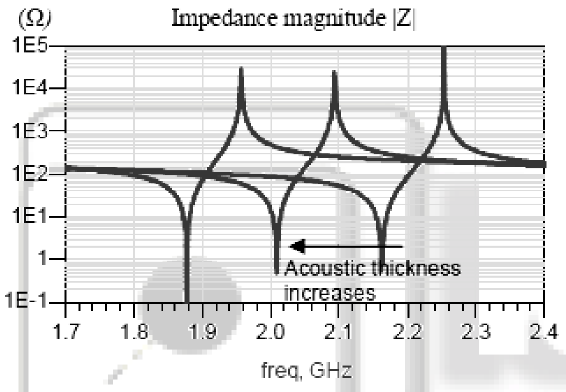

Fig. 8: Effect Of Electrode Thickness On Resonance Frequency.

As the electrode layer thickness increases as shown in Fig 7 then the resonance frequency is decreases [10]. In this way, FBAR filter act as switch as clear from Fig 8, for one particular electrode thickness resonance frequency is different from the other resonance frequency correspond to different electrode thickness.

IV. CONCLUSION

This paper presents the importance of FBAR filter in the wireless communication i.e. FBAR Filters have the characteristics of high power handling capability, high Q factors, a low volume, good thermal stability, a low cost and compatible with IC chip integration. Because of many mobile networks like Wi-Fi, CDMA etc. we require a FBAR filter which have the characteristics of switch in order to incorporate all functions in a single device.

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