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Hybrid FBAR Resonator Using ZNO Patterns And Study using 2D FEM Simulation

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***Abstract*: This paper presents a new simple methodology for design of Hybrid Resonators. The FBAR resonator is designed maintaining same wavelength (λ) for IDT's. The proposed design involves minimal amount of layers compared to earlier designs and structure is simple. Design model consist of Patterned ZnO structures placed in between IDT finger pairs. A Methodology for Designing Hybrid Type FBAR SAW/BAW resonators is described and its study by 2D Finite element model Simulations are mentioned in the paper. The results are optimal for the proposed design where longitudinal excitation provides greater k^2_{eff} of 0.49 than the lateral excitation**

***Index Terms*: FBAR, SMR, SAW & BAW, FEM, IDT.**

I. INTRODUCTION

Resonators are playing a vital role in many applications in the field of communication. Traditional crystal and ceramic filters are not able to operate at higher frequency ranges also they are bulk in implementation and are less immune to noise [1]. Miniaturization and emergence of MEMS technology reduced the scaling of the resonators to micro level that can operate at higher frequencies. Resonators made using these thin films are known as Film Bulk Acoustic Wave Resonators (FBAR) and surface mount resonators (SMR).

A. *FBAR* and *SMR Devices*

In SMR, it is sandwiching of several layers on one another that acts as buffer layer and over the top peizo material is excited by electrodes that placed on top and bottom of piezo layer [4]. This process may seem simple takes several steps as it includes different amount of layers. But the generated bulk waves in these are at high frequencies. Also, SMR are known for better power handing than FBAR. These have lower intrinsic temperature coefficients TCF around 20ppm/ºC. Effective spurious modes suppression can be done in SMR. While FBAR design includes less number of layers than SMR where peizomaterial is placed between electrodes suspended in the air cavity unlike buffer in SMR which acts as acoustic wave reflector supported by substrate as stand. As air is poor heat conductor, power handling capacity is reduced for the FBAR. Later on improving in the design of FBAR structure has begun to make an efficient one which provides lesser temperature coefficient, wide bandwidth and a major factor is to implement it to advance device topologies. Another disadvantage of previous FBAR is due to stress control over suspended peizo over air gap it is hard to manufacture and also maintain body stability of the FBAR. Over the period different techniques have been proposed in terms of electrodes material, size and shape improvements [6] and choosing of piezo materials [5] etc. Improvement in these to make the application such as filters makes RF communication more reliable. 3rd type of FBAR's were introduced in recent days where the implementation of design is very simple with 3 to 4 layers in device which results in less fabrication steps[3]. In the design IDT finger pairs were placed on the top of the peizo material i.e. placed along the substrate. Here operating frequency (f0) is controlled by IDT topology and only either SAW or BAW nature of the device was utilized by conversion like in effective hybrid transducer [5] for designing resonator in filter applications like ladder filters. Also their tunability Control requires addition of lumped parameters in the circuits which make the design even more complex.

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II. PROPOSED METHODOLOGY

The proposed FBAR design in the paper is structure designed so that it can keep the following goals such as it should be easier to manufacture, air gap free (increase power handling as air is poor conductor of heat) [1] also have less number of layers. Hence on basing of 3rd type FBAR and effective hybrid SAW/ BAW transducer a new Structure need to be designed that should also meet the advance topology standards.

A. Hybrid FBAR Design

For the design of FBAR keeping the above goals in consideration neglecting the air gap the alignment of the peizomaterial and electrodes should be on the same level with step like structures [8] placed over the substrate [2]. Here the peizo material is sandwiched in between the electrodes for one type and is placed over the top for other on the basis of excitation to be carried out for generation of BAW/SAW wave in the resonator. Usually the waves propagated on the same surface plane is SAW wave and into the surface is a BAW wave. Here two types of resonator structures are designed on excitation basis, one by means of lateral electrode excitation and other by longitudinal electrode excitation. As the idea is to maintain the same wavelength 'λ' for the resonator both of these are designed on same basis for lateral (transverse) and longitudinal resonator.

B. Geometry and Material Consideration

Within the Same 'λ' with electrode width taking constant as 'λ/4' the peizomaterial width (w) is to be varied within ($0<w<\lambda/4$) and height (h) within ($0<h<\lambda$).The height of the substrate can be taken as 5λ. To observe the resonance and anti-resonance response a sample is considered defining it as a periodic structure.

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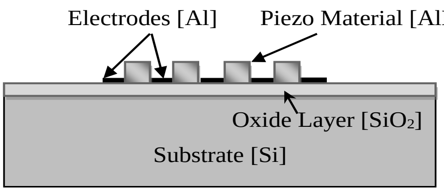
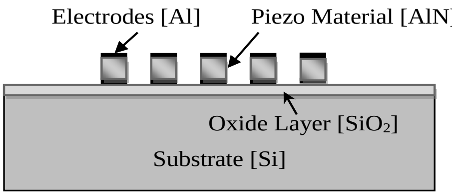
Aluminum (Al) is used for electrodes and Zinc Oxide (ZnO) as piezo material with Silicon (Si) for substrate, SiO2 for oxide. The lateral and longitudinal excited resonator are shown in below Fig.1 where ‘a’ represents laterally excited resonator for SAW while ‘b’ for longitudinal excited resonator i.e. for BAW wave generation.



(a)

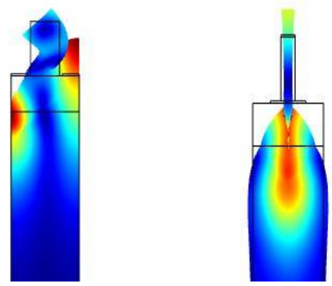


(b)

Fig.1. (a) laterally excited resonator and (b) Longitudinal excited resonator

C. Working of Proposed design

When the electrodes are placed on under the piezo as shown in Fig.2(b) i.e. the longitudinal modes (L0,L1) provides better frequency responses with larger bandwidth while for lateral excitation i.e. electrodes placed on either side of piezo material as shown in Fig.2(a) transverse modes (T0,T1,T2,T3) provides better responses for fs & fa. Now, the frequency response for the respective Eigen modes for the resonator designs are taken by point evaluation for periodic model varying the width and height of peizo material keeping electrode width constant for laterally excitation while for longitudinal keep same at bottom for top electrode width is confined up to varied piezo width.



(a) (b)

Fig.2 (a) periodic structure of lateral excited resonator
(b) Periodic structure of Longitudinal excited resonator

III. RESULTS & GRAPHS

For the above mentioned laterally excited periodic structures the admittance and S11 plots for Fig.3 are as follows

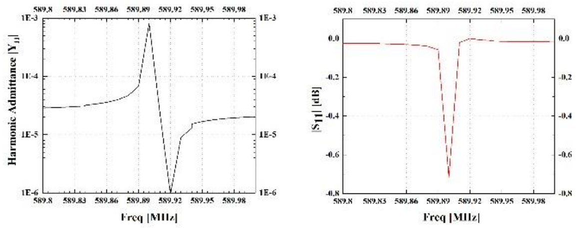
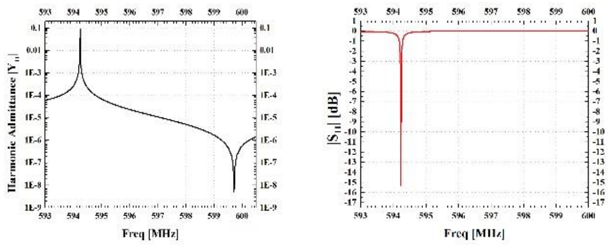


Fig.3 (a) Admittance plot and (b) S_{11} plot for lateral excited resonator periodic structure

We can see that the bandwidth is minimum for the above graph for laterally excited resonator which can be used for rejection filters and S11 is around -19.4dB for single periodic model that can be increased by adding more IDT’s finger pairs which is a real scenario as 100-400 pairs can be seen in general designs. For the above mentioned longitudinal periodic structures admittance and S11 plots for Fig.4 are as follows

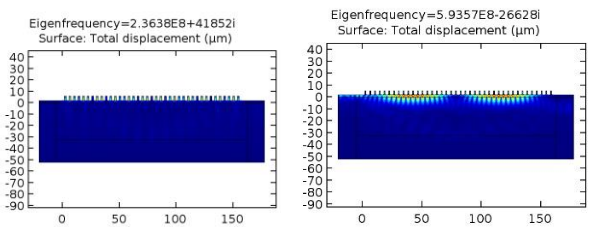


(a) (b)

Fig.4 (a) Admittance plot and (b) S_{11} plot of longitudinal excited resonator periodic structure

It can be seen from above graphs that the longitudinal excitation offers larger bandwidth than lateral excitation We can see that the bandwidth is maximum for the above graph for which can be used for band pass filters and S11 is around -15.6dB and with less λ size the Band Width further increases as k2 increases. Increase in IDT finger pairs also makes achieving k2 which can be shown in the following condition. For the designed resonator structures, considering λ=8um for IDT finger pairs of 40 electrodes for both lateral and longitudinal resonators. Perfectly matched layers (PML) are taken on either for absorption since not a periodic structure.

Mode shapes for structures shown in Fig.5 for both resonator structures.



(a) (b)

Fig.5 (a) Mode shape for lateral Excited Resonator with 40 IDT Fingers (b) Mode shape for longitudinal Excited Resonator with 40 IDT Fingers

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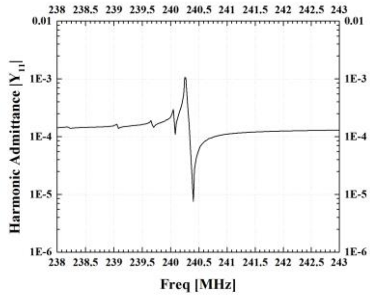
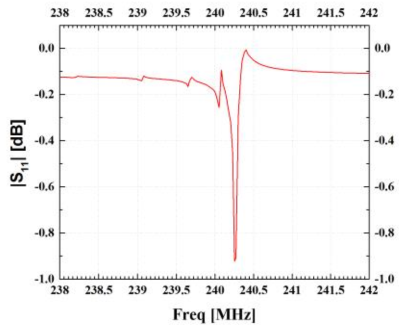
The Admittance plots and S11 parameters of lateral excited structure for 40 electrodes are taken and are plotted with respective to Frequency for Fig.5 (a) are shown in Fig.6 (a) & (b).



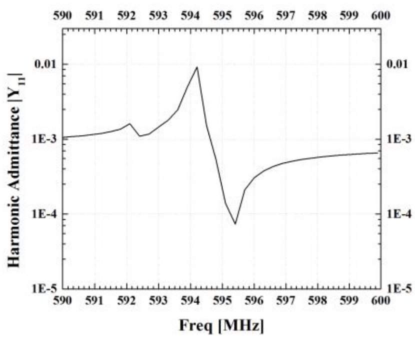
(a)



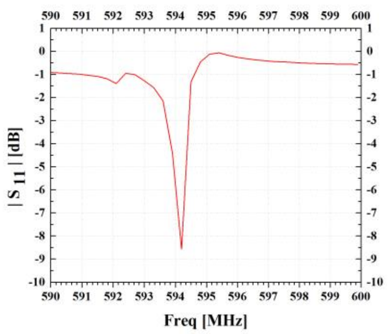
(b)

Fig.6 (a) Admittance plot and (b) S_{11} plot of lateral excited resonator periodic structure.

Similarly for longitudinal excited structure for 40 electrodes the Admittance plots and S11 parameters are taken and are plotted with respective to Frequency for Fig.5 (b) are shown in Fig.7 (a) & (b).



(a)



(b)

Fig.7 (a) Admittance plot and (b) S11 plot of lateral excited resonator periodic structure.

The BVD Model passive elements are calculated and tabulated in the below Table I.

Table I. Resonator Parameters

Hybrid Resonator type	Δ*f* (MHz)	L_m (nH)	R_m (Ω)	C_m (pF)	C_0 (nF)
Laterally Excited	0.13	0.29	50	7.1	6.6
Longitudinall y Excited	1.2	2.6	50	0.5	0.1 3

IV. CONCLUSION

A FBAR Resonator design i.e. laterally and longitudinally excitable combined as a Hybrid maintain the same λ is proposed and 2D Simulations using Finite Elemental Model from COMSOL 5.2 are presented in this paper. Both BAW and SAW wave nature are utilized by placing peizo material alternately on IDT's in transverse and longitudinal to achieve frequency response with optimal parameters.

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