Investigation of Saw Devices with Buffer Layer on Si Substrates

Jaya Krishna Akella, Kireeti Sarvardhapu, Sai Krishna

***Abstract*: This paper presents on Investigation of behavior of buffer layer on the Conventional SAW devices and their dispersion characteristics. The Conventional SAW devices designed on non-piezoelectric substrate with buffer layer exhibit different characteristics. The SAW device has the arrangement of Patterned ZnO/IDT/AlN/Si and AlN/ZnO as the buffer layer and their corresponding analysis are done by 2D Finite element model Simulation. Different Characteristics such as temperature dispersion and Phase velocities with respect to varying a buffer layer height are taken and mentioned which produces optimal results are proposed in the paper.**

***Index Terms*: SAW/BAW, IDT,TCF, FEM.**

I. INTRODUCTION

SAW devices plays a vital role in many applications in the field of communication. Usual application of SAW devices include resonators and delay lines. SAW devices have unique advantages. SAW devices are widely employed as the Pulse compression radar filters, oscillators and narrow band pass filters for commercial applications [1] and suitable for various application with frequency ranges from 10 MHz to several GHz.

A. Effect of buffer layer on Conventional SAW devices

Usually there are different methods employed for the generation of waves in the elastic medium either on piezoelectric or non-piezoelectric substrates but the characteristics of the wave generated over these mediums re influenced on various parameters such as number of IDT fingers, pitch and nature of the material considered and their properties etc.[6-8]. also another major thing the number of layers of thin films on the SAW device designed it is because thin film layer addition or removal over the substrate on the SAW devices changes the geometry scale as well as medium nature due to their different absorption and reflection coefficients.

The wave generated on the substrate due to excitation maybe a bulk wave or a surface wave. Mode conversion of the Surface wave to bulk wave or vice versa is also dependent on the thin film layers on the substrate [2]. In practical, BAW devices earlier were used to be implemented as Surface mounted resonator (SMR) structures. These structures used to have a stack of thin film layers one over another which acts a Bragg reflector for the making of standing wave pattern of the

Bulk wave within the substrate. Here the Bragg or acoustic wave reflector acts as a buffer layer in the SMR resonator structure for the bulk wave generation similarly in the SAW Devices implemented by means of film bulk acoustic wave resonator. In earlier FBAR structures, there used to be suspended medium in air with electrodes on either side over the substrate [4]. The air gap or vacuum here used to be the buffer layer i.e. a dielectric medium these acts a poor conductor and leads to decrease the power handling capacities of the devices. With the edge reflection SAW devices coming into picture where no air gaps are observed in the device there is no presence of buffer layer on the device. The stability and confinement of the device are much altered than the previous conventional SAW devices.

II. METHODOLOGY

In the methodology, buffer layers of ZnO/AlN are placed on the recent SAW devices and the characteristics like dispersion and temperature coefficient factor (TCF) etc. are studied by 2D finite element simulations using COMSOL Multiphysics In the following investigation height of ZnO and AlN peizomaterial that acts as buffer layer are varied and their respective variation in parameters such as phase velocities, coupling coefficient, TCF etc. are observed.

III. INVESTIGATING THE DESIGN USING PERIODIC STRUCTURES

For the study of the effect of buffer layer on the SAW devices. A periodic structure is considered which is given with a wavelength of $\lambda/2$ (um) and electrodes of 0.1 um height are placed of width $\lambda/4$ and piezo material of width $\lambda/8$ is taken and is placed with perfectly matched layers on either sides and bottom for absorption. The height of the buffer layer is kept as a variable and parameterized to observe the phase velocities and temperature dispersion with respect to altered height, upon the excitation of electrodes the SAW devices behaves like resonator producing different Eigen modes. These Eigen modes involves of both Transverse and longitudinal modes of different orders such as for Transverse modes are indicates as T_0, T_1, T_2 and T_3. For longitudinal modes are indicates as L_0, L_1.

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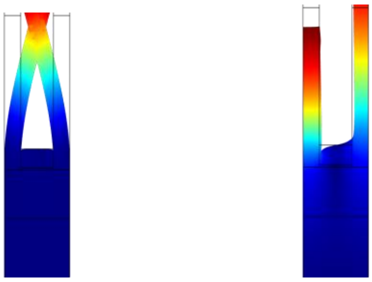
Jaya Krishna Akella, Department of ECE [VLSI], Koneru Lakshmaiah Education Foundation, Guntur, India.

Kireeti Sarvardhapu, Department of ECE [VLSI], Koneru Lakshmaiah Education Foundation, Guntur, India.

Sai Krishna, Department of ECE, Koneru Lakshmaiah Education Foundation, Guntur, India.

Each of these modes shows different displacement varying phase velocity and confinements of generated waves in the SAW Device



(a) (b)

Fig.1. (a) Transverse mode & (b) Longitudinal mode of SAW device

Fig.1 (a) Shows the Transverse mode of periodic structure of the SAW device where wave propagation is observed on surface of the substrate while in Fig.1(b) shows the Longitudinal mode where wave propagation is observed into the substrate. The respective phase velocities can be calculated from the following equation (1)

$$v = f * \lambda \quad (1)$$

Where *v* is the Phase velocity of wave λ is wave length and *F* is Frequency. Temperature coefficient of all the patterned structures is found by using the formula

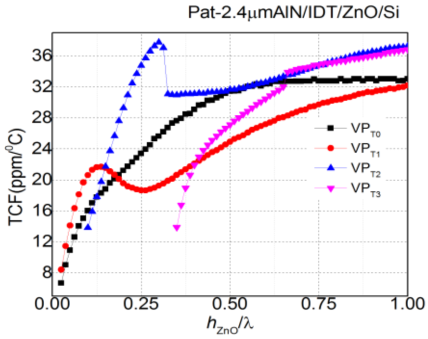
$$\mathrm{TCF} = \frac{v_{35} - v_{15}}{2\Delta T v_{25}} \quad (2)$$

Where v_{35} is phase velocity at 35°C temperature, v_{15} is phase velocity at 15°C temperature, v_{25} is phase velocity at 25°C temperature, ΔT is change in temperature

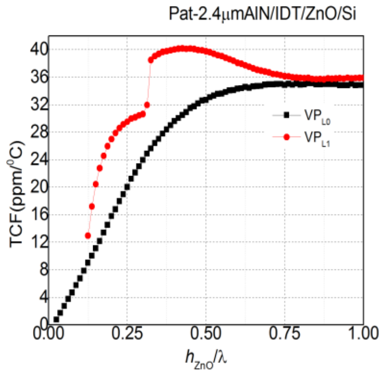
For all the patterned structures, we considered the non-piezoelectric substrate silicon. For the silicon the anisotropic property elasticity matrix variations with temperature is considered. While for the piezoelectric films both the density and elasticity matrix varies with the temperature. Constant room temperature 25°C is considered during simulation. Further we use the variable temperatures like 15° or 35° temperatures. So, the change in temperature is always 10°C. We will calculate the velocities at these temperatures with respect to the height of the variable piezoelectric material. Finally, we will calculate the TCF value for the given structure.

III. RESULTS & GRAPHS

In Fig 2(a) proposed buffer layer structure of 2.4µm Pat-AlN/IDT/ZnO/Si vertically polarized modes produced by transverse wave. The 0th and 1st mode starts at h_{ZnO}/λ=0.025 with TCF values of 6.68ppm/°C and 8.41ppm/°C which are minimum. The 2nd mode starts at h_{ZnO}/λ=0.1 with minimum TCF value of 13.8ppm/°C. The 3rd mode starts at h_{ZnO}/λ =0.35 with minimum TCF value of 13.9ppm/°C.



(a)



(b)

Fig.2. TCF dispersion curves, (a)for transverse waves (b)for longitudinal waves

In Fig 2(b), for the proposed buffer layered structure 2.4µm Pat-AlN/IDT/ZnO/Si vertically polarized modes produced by longitudinal wave. The first mode VP_{L0} starts at h_{ZnO}/λ= 0.025 with minimum TCF value of 0.71ppm/°C. The second mode VP_{L1} starts at h_{ZnO}/λ=0.125 with minimum TCF value of 13.1ppm/°C.

In Fig 3(a)For proposed buffer layer structure of proposed buffer layer structure 2µm Pat-ZnO/IDT/AlN/Si vertically polarized surface modes produced by transverse wave. The 0th and 1stmode starts at h_{AlN}/λ=0.025 with TCF value of 17.4ppm/°C and 26.62ppm/°C which are minimum and In Fig 3(b), for the proposed buffer layered structure Pat-2µm ZnO/IDT/AlN/Si vertically polarized surface modes produced by longitudinal wave. The 0th mode starts at h_{AlN}/λ=0.025 with TCF value of 7.22ppm/°C which is minimum.

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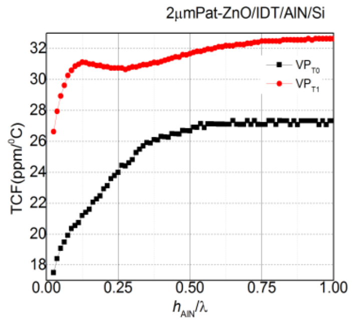
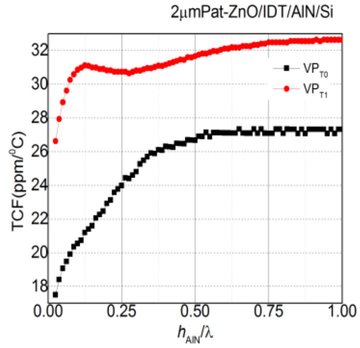


(a)



(b)

Fig.3. TCF dispersion curves, (a) for transverse waves (b)for longitudinal waves

In pervious section we have discussed about the dispersion of the phase velocity, the dispersion was caused when the height of the ZnO or AIN will increase the phase velocity will decreases, we have seen some of the results with varying of height of ZnO and AIN. For structured pattern of AIN/IDT/Si where we will observe the high phase velocity of 672MHz and we have observed the varying of height of ZnO and AIN of 0.8µm,1.4 µm and 2.5 µm, 2 µm with respectively, for these height variations the phase velocity is getting decreased.

Fig.4. Phase velocity plot for patterned AlN/IDT/Si

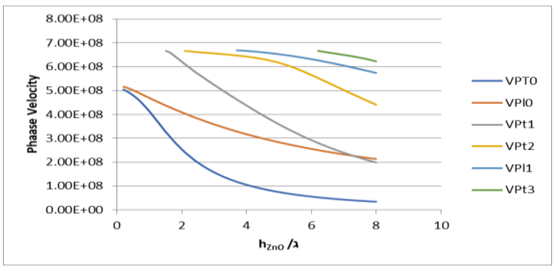


Fig.5. Phase velocity plot for patterned AlN/IDT/0.8µm ZnO/Si

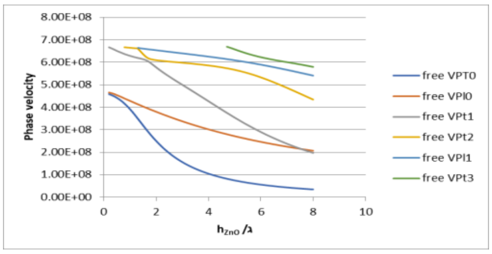


Fig.6. Phase velocity plot for patterned AlN/IDT/1.4µm ZnO/Si

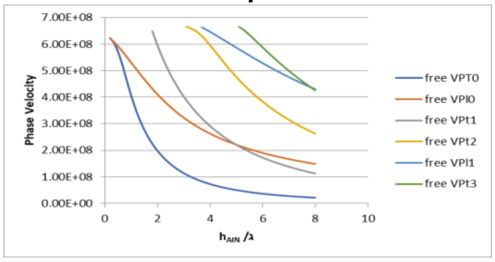


Fig.7. Phase velocity plot for patterned ZnO/IDT/2.5µm AIN/Si

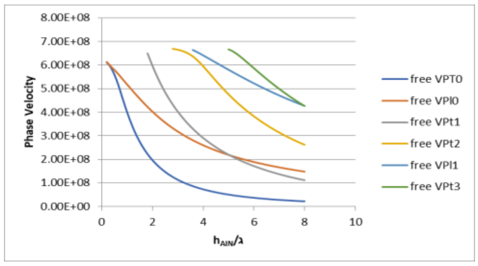


Fig.8. Phase velocity plot for patterned ZnO/IDT/2µm AIN/Si

IV. CONCLUSION

The structured pattern of the AIN/IDT/Si having K^2 is only 0.432% So we have proposed a buffer layer structured pattern of ZnO/IDT/AIN/Si by varying a ZnO height at 2µmZnO/IDT/Si having K^2 of 3.10% comparing to normal and buffer layer structured the K^2 have been increased to high. By changing the IDT in the proposed structure there is change in both phase velocity and K^2. The minimum TCF observed for the reference structure is zero while it is 0.6125ppm/°C for the proposed buffer layer structure patterned ZnO/IDT/2.5µmAlN/Si. This shows that our proposed buffer layer structure is more efficient than the reference structure.

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