A Review on Surface Acoustic Wave Sensor

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***Abstract*-- Surface Acoustic Wave (SAW) technology can be applied to create highly sensitive biosensors due to its extreme sensitivity to surface perturbation. The velocity of an acoustic wave depends upon the mass, density and stiffness of the piezoelectric substrate. The binding of antigens with antibodies, when immobilized in the path of the traveling wave, changes the mass of the biolayer. The mass loading effect perturbs the surface boundary which changes the velocity of the wave and consequently shifts the frequency of the traveling SAW. With a pair of transmitting and receiving Inter-Digitated Transducers (IDT), high frequency SAWs can be generated through radio frequency interrogation at the free surface of piezoelectric material. In the future, bio-molecule immobilization and optimization of the sensors are necessary to develop fully functional devices.**

***Keywords:* SAW sensor, Inter-digitated transducer, piezo-electric materials, MEMS.**

I. INTRODUCTION

Micro Electro Mechanical Systems (MEMS) technology is a process technology used to create timing integrated devices or systems that combine mechanical andelectrical components. MEMS technology exploits the existing microelectronics infrastructure to create complex machines on a micrometer scale. Extensive applications for these devices exist in both commercial and industrial systems. Well-known components such as integrated silicon pressure sensors, accelerometers and motion detectors have found use for several years in automotive and industrial applications.

Biosensor is an analytical device used for the detection of an analyte that combines a biological component with a physicochemical detector.

SAW sensors are a subset of acoustic wave sensor devices. Acoustic wave sensor are very versatile in that they may be used alone or as a part of a filtered sensor to measure many phenomena.

II. MOTIVATION

The early detection of cancer can significantly reduce cancer mortality and saves lives. Thus, a great deal of effort has been devoted to the exploration of new technologies to detect early signs of the disease. They can be used for risk assessment, diagnosis, and prognosis and for the prediction of treatment efficacy and toxicity and recurrence.

III. BIOSENSOR

Biosensors work with the principle of the interaction of the analytes that need to be detected with biologically derived bio-molecules, such as enzymes of certain forms, antibodies and other form of protein. These biomolecules, when attached to the sensing element, can alter the output signals of the sensors when they interact with the analyte. Proper selection of biomolecules for sensing elements can be used for the detection of specific analyte.

Importance of Biosensors

Biosensors have expanded giving rise to a vast frontier of interdisciplinary research that combines biology, analytical chemistry, physics and bio-electronics. From the first bulky biosensors built as academic curiosity, the field has shown a great deal of attractiveness thus becoming a research area that has successfully commercialized devices for multiple applications in a market that is worth many billion dollars. Different uses in medico-clinical, environmental, food-agricultural, security and forensic science, and other fields are making these devices increasingly popular. The question of defining what can be considered as a biosensor is difficult, but the most accepted concept nowadays is to be a device comprising of a biological recognition element attached or integrated into a transducer.

Application of Biosensor

Biosensors have been applied in many fields namely food industry, medical field, marine sector etc., and theyprovide better stability and sensitivity as compared with thetraditional methods.

Types of Biosensors

There are different types of biosensors based on the sensor devices and the biological materials and some of them are discussed below.

1. Electrochemical Biosensor

Electrochemical biosensor is a simple device. It measures the measurement of electronic current, ionic or by conductance changes carried by bio-electrodes.

2. Amperometric Biosensor

The biosensors are based on the electron's movement, i.e. electronic current determination as a reaction of enzyme-catalyzed redox reaction. Generally a normal contact voltage passes through the electrodes to analyze. In the enzymaticreaction which produces the substrate or product can transfer the electrons with the surface of electrodes to be reduced.

As a result an alternate current flow can be measured. The substrate concentration is directly proportional to the magnitude of the current. The reduction of oxygen is acquired through the oxygen electrodes and it is a simple way to from an amperometric biosensor.

3. Blood Glucose Biosensor

These are used widely throughout the world for diabetic patients. It has single use disposable electrodes with glucose oxide and derivatives of a mediator (ferrocene) and the shape of the blood glucose biosensor looks like a watch pen. With the help of hydrophilic mesh electrodes are converted. The blood glucose biosensor is a good example of amperometric biosensor.

4. Potentiometric Biosensor

In this type of biosensor, changes in the concentration of ions are determined by the ion-selective electrodes. In this, pH electrodes are used most commonly. Hence a large amount of enzymatic reactions is involved in the release of hydrogen ions. Ammonia-selective and carbondioxide selective electrodes are some other important electrodes.

The potentiometric electrode and the reference electrode can be measured with the help of potential difference and it is directly proportional to the substrate concentration. The potentiometric biosensor is the sensitivity of enzymes to ionic concentration like H+ and NH+4.

The ion-selective field effect transistors are lower price devices. It can be used in the miniaturization of potentiometric biosensors. The example of the ion-sensitive field effect transistor biosensor is to monitor intra-myocardial for open heart surgery.

5. Conductometric Biosensor

In the biological system there are several reactions that change the ionic species. The electronic conductivity can be measured with the help of an ionic species. The example of the conductometric biosensor is the urea biosensor which utilizes the immobilized areas.

6. Thermometric Biosensor

There are many more biological reactions which are connected with the production of heat and it forms the basis of thermometric biosensors.

7. Optical Biosensor

The optical biosensor is a device, which utilizes the principle of optical measurements like fluorescence, absorbance etc. They are used in fiber optics and optoelectronic transducers. The optical biosensors are safe for non electrical remote sensing of materials. In the transducer elements, primarily optical biosensors involves in the enzymes and antibodies. Usually the biosensors are not required for any reference sensors and the comparative signals are generated by using the sampling sensor.

8. Fiber Optic Lactate Biosensor

The working of the fiber optic lactate biosensor is based on the measurement of change in oxygen concentration, moleculared by identifying the effects of oxygen in fluorescent dye.

The oxygen depends on the amount of fluorescence generated by the dyed film this is because of oxygen has a reducing effect on the fluorescence. In the reaction mixture the concentration of lactate is increased, oxygen is utilized and as a result, there is a proportional decrease in the quenching effect. Hence there is an increase in the fluorescence output that can be measured.

9. Optical Biosensor for Blood Glucose

For the diabetes patients the blood glucose is more important to monitor. For this simple technique is used, i.e. Paper strips saturated with the reagents it contains glucose oxide, horseradish peroxidase and a chromogen. Using the portable reflectance meter it can measure the intensity of the color of the dye. In world wide the glucose strip industry is very high. The calorimetric test strips of cellulose covered with the suitable enzymes and reagents are in use for the view of more blood and the urine parameters.

The other optical fiber biosensors are used in the devices of optical biosensing it measures the p CO_2 and in critical care and in surgical monitoring.

10. Piezoelectric Biosensor

The principle of piezoelectric biosensor is used in sound vibrations; hence it is called acoustic biosensors. The basics of the biosensors are formed by the piezoelectric crystals and the characteristic frequencies are tremblingwith the crystals of positive and negative charge. By using the electronic devices we can measure certain molecules on the crystal surface and alters the response frequencies using these crystals, we can attach the inhibitors. The biosensors for cocaine in the gas phase have been developed by attaching the antibodies cocaine to the surface of the crystal.

11. Immuno Biosensor

These sensors work on the principle of immunological specificity and mostly coupled with measurement on the potentiometric biosensors. There are different configurations of probabilities for immuno biosensors some of them are given below,

- The immobilized antibody can directly combine through the antigen
- The immobilized antigen can combine with the antibody which can twist to a second free antigen
- The immobilized antibody combined with the free antigens and enzyme labeled antigen in opposition

12. Surface Acoustic Wave Sensor

These sensors belong to various classes of MEMS which depends on the modulation of the SAW to detect certain physical phenomenon. These devices transduces one form of energy to another specifically electrical to mechanical and mechanical to electrical, this conversion is required as the mechanical signals are more sensitive or influential to physical phenomenon than that of the electrical signals. At the output the changes in certain parameters (amplitude, phaseand frequency) describe the presence of the desired physical phenomenon and the same is measured. Biosensor comprises of biochemical recognition system and a transducer which transforms the biochemical (biological) response into a measurable output signal. It allows detection of analytes over relevant concentration ranges.

IV. DESIGN OF SENSOR USING COMSOL

This shall provide an insight to the design and simulation of the SAW biosensor using COMSOLtool. Here first the designing and simulation using COMSOL is seen and later sensor process flow and simulation is done using Coventorware tool.

There are various parameters that are to be considered while designing the sensor, more specifically the application for which the device is designed will determine the importance of the parameters. The factors that define the structure of the device are:

- Size, efficiency and sensitivity
- The mode of propagation on the surface of the materials (wired or wireless)

The market for which the device isdesigned will determine the cost of the device; these are to be considered while designing of the device. These when considered will help the designer in determining the system parameter and the material that can be chosen.

There is a need for considering many important device characteristics, prior to considering the parameters for SAW sensor design; these characteristics are physical size, bandwidth, operating frequency, frequency response and impulse response.

Synchronous Frequency (f_o)

This can be defined as the frequency (f) that is generated in the neutral environment by the SAW propagating along the surface. The neutral environment can be defined as the environment in the absence of any measurand, practically during initial testing of the device. It is seen that the sensitivity will be highest at the synchronous frequency and also that the frequency of the electrical input (AC input) is always equal to the synchronous frequency in-order to have maximum efficiency. The parameter that is important in determining the synchronous frequency is pitch (p).

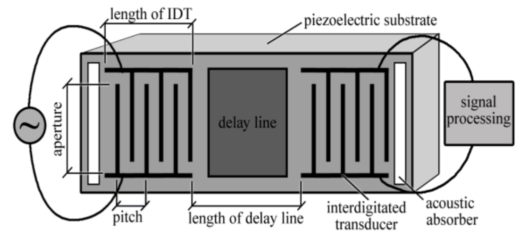

Figure 2: General Structure of Sensor

The consecutive fingers or the alternating interdigitated transducer are always of opposite voltage considering it as a sinusoidal AC signal. These fingers locate the maximum strain along the compression and tension. The wavelength of the transduced mechanical wave by the substrate is equal to the pitch. The below figure shows the generation of the sinusoidal signal.

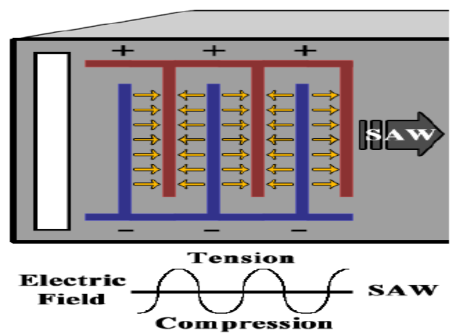

Figure 3: Sinusoidal Wave Generation

The relationship of the synchronous frequency is given

by the expression below:

$$f_o = V_p P \qquad (1)$$

where,V_p denotes the propagation velocity, this is a material property and it is necessary that the output IDT must have the pitch like the input IDT.

Bandwidth

The bandwidth for a signal can be defined as the upper and lower levels of frequency at which the attenuation is 3dB of the maximum amplitude. For the acoustic wave generated by input IDT the bandwidth provides frequency distribution ranges. While increasing the number of fingers for an IDT will help in increasing the bandwidth for the given frequency.

$$BW = 2foN \qquad (2)$$

Substituting equation 1 in equation 2

$$BW = 2N_pV_p = 2V_p\, l_{IDT} \qquad (3)$$

where, l_{IDT}=Total length of the IDT

To create a more distinct signal the amplitude of the synchronous frequency is increased with respect to the nearby frequency, by minimizing the bandwidth.

Physical Size

This parameter defines for which application and the material is to be considered, the minimum device dimensions can be defined by the pair of IDTs, delay line and absorbers if present.

To represent length in terms of pitch and frequency,this can be represented as follows

$$l_{IDT} = PN = Nf_0V_p \quad (4)$$

The equations 1, 2, 4 provides a certain limitation, for a lower frequency range the pitch is larger and the bandwidth would be low, hence a large size sensor would be required. The average frequency range for the SAW device is 10MHz to 3GHz with the pitch size being 1µm to 300 µm.

The delay line size are dependent on the measurand nature and the interaction with the SAW, for the applications where the phase shift or time delay is measured, the delay line length that is equal to the change that are observable. Now let us consider the width of the piezoelectric substrate, it is necessary to consider the same as it defines the maximum length of the IDT. The pitch width must be much lesser than that of the width of the IDT also that the horizontal distance between the IDT must be minimized. There must be good balance in the thickness of the material in-order to avoid premature failure of the device, also there exists a limitation to how thin the material can be made, also that most of the piezoelectric materials are crystalline in nature.

Material Selection

While designing of the device it is necessary for the material to be selected for both the piezoelectric substrate and IDT.

Piezoelectric Substrate

As it is learnt from the few previous explanations that the piezoelectric materials are crystalline in nature, so for this type substrates it is necessary to consider both material and the crystal orientation in order to have adesired properties. Properties that are to be considered are coefficient of thermal expansion, wave propagation velocity, electromechanical coupling factor, compatibility techniques and cost of fabrication. The thermal expansion coefficient will define the change in length of the material, as the temperature is changed. Electromechanical coupling factor defines how efficiently the energy can be transduced in the system; wave propagation velocity will define the various properties related to the design. Here the piezoelectric substrate is PVDF.

V. COMSOL

The simulation of SAW device is done using COMSOL Multi-physics tool, this tool is Finite Element Analysis (FEA), solver and simulator software package that is widely used for the physic and engineering applications. It is general purpose software with a progressed numerical solving method for simulating and modeling different physic-related problem, it has many built in physics like AC/DC, acoustic, piezoelectric etc. It also can perform various studies like stationary, frequency dependent, time dependent etc.

Designing

It is necessary to first define the velocity of the wave propagating on the surface of the device, so here the Rayleigh wave is considered since a hybrid material configuration is used, the velocity of the wave being 3996 m/s, this can be represented as

$$vR = 3996 \text{ m/s} \quad (5)$$

Once the velocity of the wave propagation is defined it is necessary to define the target frequency, the target frequency for the SAW is 433 MHz. so,

$$f_o = 433 \text{ MHz} \quad (6)$$

Then the target wavelength is computed with equations 5 and 6 so the expression becomes,

$$\lambda o = vRfo \quad (7)$$

Once the target frequency and target wavelength is determined next it is necessary to denote the width and height of the IDT, so the same can be determined by using the following expressions below,

$$w_o = 4\lambda o \quad (8)$$

The above expression is for width of the single electrode in the IDT. Now the height of the single electrode IDT can be represented by the below expression 9,

$$h_o = 5\lambda_o \quad (9)$$

The figure 4 shows the width and height of the electrode on the single side of the IDT.

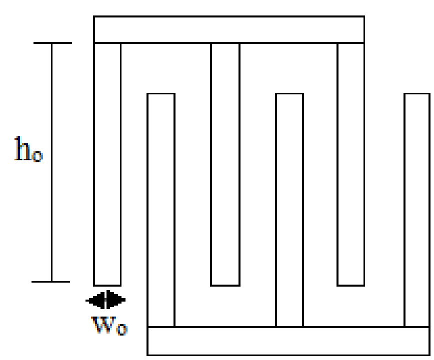

Figure 4: Width and Height of the Electrode

Next the expression for horizontal gap between the two ports i.e. the gap between input IDT and output IDT is obtained,

$$port\_gap = 3\lambda_o \quad (10)$$

The vertical gap between the terminals on single side of the

IDT configuration,

$$term\_gap = \lambda_o \quad (11)$$

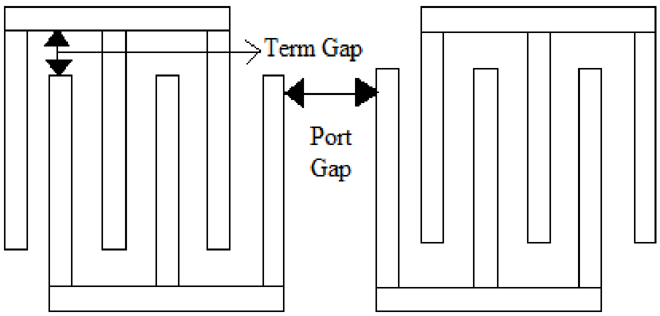

Figure 5: Term gap and Port gap of IDT

The pitch can be defined as the distance between the consecutive electrodes of the each terminal. This pitch is useful in determining the wavelength of the acoustic wave. The expression is

$$p = 4w_o \quad (12)$$

The material used here is Polyvinylidene Fluoride (PVDF), the earlier section provides information on how the materials are selected the material properties of PVDF is mentioned in the same section. The IDTs are made of gold due to the properties mentioned in the table 2 also that gold has higher electrical conductivity this material is ductile and malleable. The pure gold has melting point 1064 °C and electrical resistivity of 0.22μΩm, lastly gold does not tarnish.

Table 1: Properties of Gold

Property	Name	Value	Unit
Relative Permittivity	Epsilon	6.9	1
Density	Rho	19300	kg/m^3
Young's Modulus	E	70e9	Pa
Poisson's Ratio	Nu	0.44	1
Thermal Expansion Coefficient	Alpha	$14.2e^{-6}$	1/K
Thermal Conductivity	K	317	W/(m*K)

Meshing

The simple idea of meshing is that the larger block or model is divided into number of pieces and then for each piece the stress is calculated, lastly combine all the pieces to make a model or a block or component. If the density of meshing is larger, then greater is the accuracy of evaluation but there exist larger difficulty in comprehending the problems. The meshing is done once the model is built and materials are added. There are types of meshing method that can be used, they are tetrahedron, swept, quad, triangular, prism and pyramids. The use of the type of meshing would depend on the applications, for example the tetrahedron is used for all the models its one of the simplex type of meshing, the others are used when they are required.

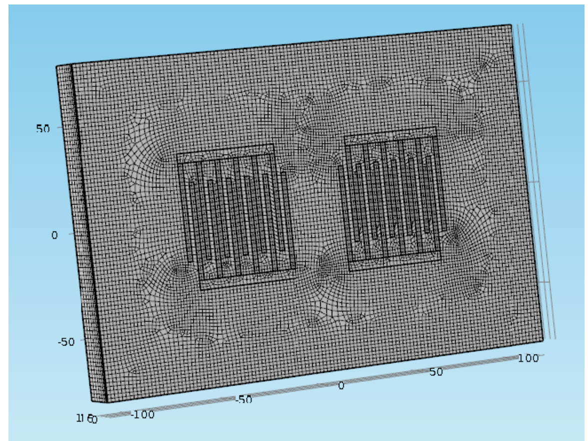

Figure 6: Meshed Structure

After the meshing is done the last part is to compute the result then to analyze the result.

VI. MODEL PREDICTIVE CONTROL FORMULATIONS, PROPERTIES AND REVIEW OF THE LITERATURE

Cancer Bio-mark Detection using SAW Sensor

Cancer is a leading life-threatening disease all over the world with over 200 types of cancer identified and more than 1500 deaths occurring each day. The conventional methods, including ultrasound, magnetic resonance imaging, and biopsy are inefficient for early stage cancer detection as these methods depend on the phenotypic properties of the tumor. The molecules which undergo prominent alterations during cancer are recognized as biomarkers and have high clinical significance. Biomarkers may be nucleic acids, proteins, metabolites, isoenzymes or hormones and are classified as diagnostic, prognostic and predictive. Diagnostic biomarkers are related to the detection of the disease, whereas prognostic biomarkers offer information about the course of recurrence of the disease. The presence or absence or change in the level of the specific biomarkers in a cell often indicates cancer development. Cancer-specific identification and detection of these biomarkers could help in early diagnosis and monitoring disease progression. All cancers are multifactorial and associated with multiple events in the cell involving more than one molecule. Therefore, simultaneous detection of multiple biomarkers is essential for correct diagnosis.

The focus of clinical cancer diagnosis is to develop analytical techniques, which are explicitly capable of sensitive and parallel detection of biomarkers rendering useful point-of-care testing. In recent times, there is a growing interest in developing cancer biosensors as they show superior analytical performance and real-time measurement. Because of their lower minimum detection limits, they can measure very low levels of biomarkers in physiological samples which can assist in the diagnosis of cancer at an early stage. Besides, they also facilitate the reuse of biorecognition molecules and avoid a time lapse between the sample preparation and analysis. Moreover, biosensors show high potential for simultaneous detection of multiple biomarkers. In this review, we have discussed the established molecular alterations and related biomarkers in cancer. Latest design and fabrication approaches of biosensors to detect these cancer biomarkers are addressed. In comparison to the earlier biosensor, this highlights the analytical performance of these biosensors in terms of sensitivity, stability, linear detection range and detection limit obtained with various fabrication strategies.

The author in [2] of this paper suggests how the SAW devices can be used for passive wireless sensors, where these types of radio sensors makes it conceivable to peruse estimation at the remote areas by considering its values. The definitive advantage of this type of sensors is that their passive operations with no requirement for a different force supply and falls in the likelihood of wireless establishment at especially inaccessible areas. It is also by fact that these sensors are free from maintenance and the waves that travel along the surface can be used to detect the presence of the chemical compound by change in the properties of the wave. This paper also helps in comparing various type of SAW sensors (reflective delay line, resonators and dispersive) and their equations for sensitivity calculation and also provides example for different applications.

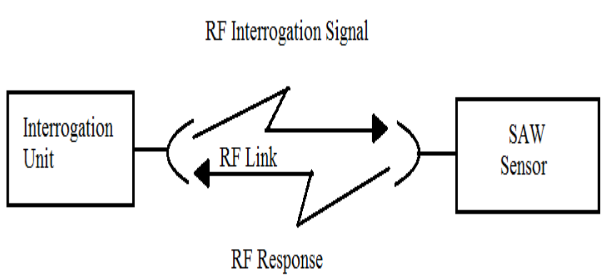

Figure 7: Schematic of Wireless System using SAW Sensors [2]

The paper provides the application of the SAW sensor which are temperature sensor (to detect temperature), sensors van be used to detect mechanical properties (pressure, acceleration) and physical and chemical properties (to detect different chemical). The dispersive based sensor has greater advantage as it has adjustable sensitivity.

Now having learnt the application of SAW sensor from the previous author the next author in [3] defines one such application were the SAW sensors are used to monitor the tire pressure incars/road vehicles and this monitoring is continuous as it is done at even period of driving. The authors provide a prototype of the application and also provide the enhanced version of the interrogation setup. The methods for implementing are shown in figure 8.

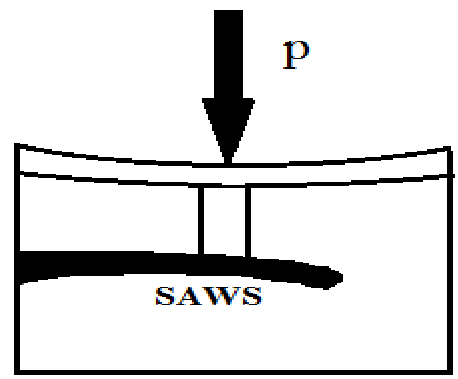

Figure 8(a): Membrane Changing Pressure [3]

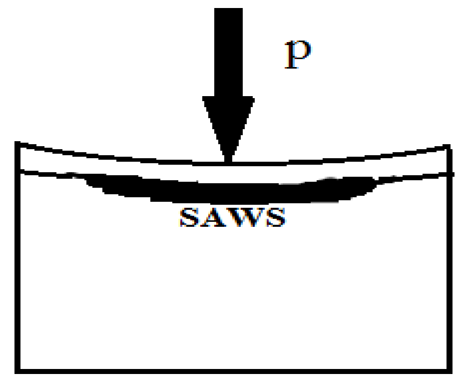

Figure 8(b): SAWS Fit to Membrane [3]

This paper concludes that SAW sensors are best for vehicular application for tire pressure measurement and the sensors are maintenance free.

The author in [4] has developed a remote sensing device for detection of temperature and pressure using SAW sensor, here the two frequency outputs of the SAW resonators are used for temperature and pressure measurement. This type of sensors have two resonators places on a single substrate with a different wave propagation directions, if there exists any variations in the velocity of the wave then desired parameters are detected. The prime aim is to reduce the noise that gets added up due to RF link between interrogation unit and sensor. The output signal is in the form of difference in frequency.

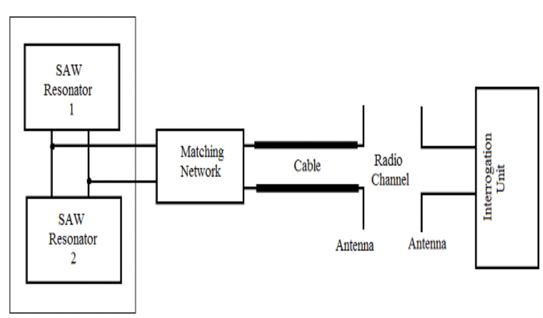

Figure 9: Basic Circuit [4]

Thus it is concluded that the disturbance in the RF link is removed and the accuracy was improved to 51.5 dB.

The author in [5] has improved the work carried out by the author in [3] where in the previous work only the tire pressure was monitored; here in this paper [5] the author monitors both tire pressure and also the thread wear and temperature. Thus, the author calls it an intelligent tire. The key factors are the contact amongst the tire and surface of the road, while portraying the acceleration, deceleration and to steer the vehicle. Therefore the contact becomes imperative for modern vehicle control system. It is also seen that the friction co-efficient can be measured by assessing tire's mechanical strain using the contact.

The author in [6] describes the use of SAW devices in harsh environment, where the author has used langasite as the material to detect the temperature and gas concentration. It provides the information on oxygen gas sensor implementation. The experimental results are also provided for the langasite SAW oxygen sensor, the sensing layer for these sensors is made of tin oxide. It also provides the information on the resistivity of ZnO and tin oxide, also the designing and fabrication of the sensor is mentioned.

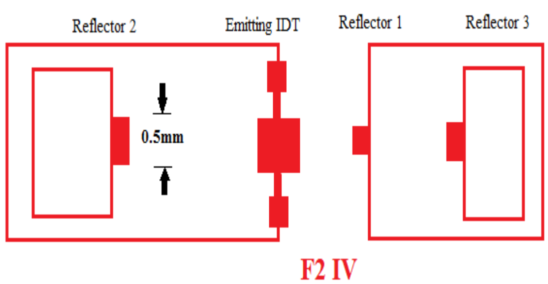

Figure 10: Mask Layout of the Sensor [6]

The author in [7] defines the designing and fabrication of the transducer in SAW sensor using the conventional lithography technique where the author investigates the importance and the conduct of the fingers in the IDT that can be used for biosensor application, here the conventional lithography technique is used, also the paper provides the combination of substrate and IDT material to be used. In the paper it is suggested that in

order to get good result concerning frequency response and electrical characterization a blend of ZnO piezoelectric substrate and aluminum IDT must be considered. It also suggests that increasing the number of IDTs in a sensor will provide a better sensitivity with an increase in the centre frequency up to 2.40 MHz

This paper has helped by providing explanation of theoretical background where different relations were obtained and also the paper defined IDT fingers (N), width of fingers and spacing between IDT, aperture length (W) and wavelength (λ).

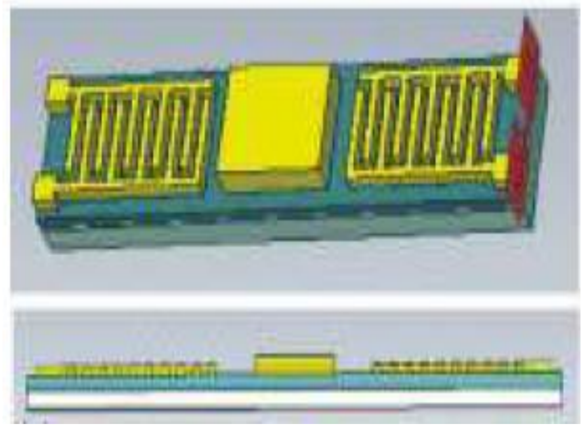

Figure 11: Structure of Biosensor with IDT

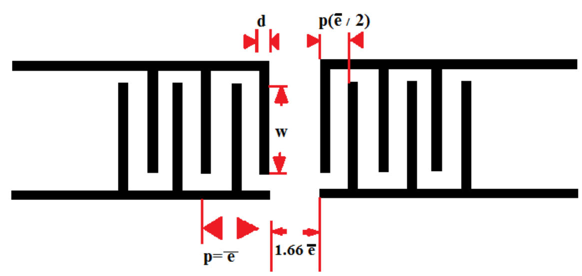

Figure 12: Design of IDT

The device was also fabricated in order to fabricate the complete device the mask must be designed.

In this paper the mask is designed by using AutoCAD software. The sensing area is in the shape of a rectangle were the size was 4800 µm x 3000 µm. This paper concludes that higher the centre frequency then better will be the sensitivity of the biosensor device;the two models were prepared one with 10 fingers IDT and other with 16 fingers IDT. The centre frequencies were 1.92MHz and 2.40MHz respectively so the IDT design with 16 fingers IDT has a higher sensitivity.

The author in [8] provides a general idea of the SAW sensors where the author describes the concepts that are important while designing and fabricating the SAW sensors. The author gives a clear idea on how one must start with the designing in the series of step where the author first explains the basic theory of operation of such sensors. It is seen that first the radio frequency source is applied to the input IDT and the input signal is converted into mechanical wave due to compression and tension. The IDT has two terminals in which one acts as a input terminal and other acts to be grounded, due to this terminal configuration a sinusoidal wave is created and the waves propagate along the surface of the substrate.

Then the wave reaches the sensing area which is coated with certain antibody, when the antibody detects the desired antigen and stick to the antibody the propagating will undergo change in velocity, phase, amplitude and frequency. The wave reaches the output IDT and the waves are converted to electrical parameter. Therefore the change in the wave properties is measured in order to detect the presence of certain antigen. The author explains how the piezoelectric materials are selected and the Rayleigh wave velocity concept as both of these factors are interconnected with one another, here the authors also explain how the material are selected for IDT and the effect of using the same materials.

The fabrication processes are also mentioned which have been useful in fabrication of the device; the processes are lift-off and etching process respectively. The final result explains few applications of the SAW sensors for the detection of various properties like physical and chemical. The main restriction to the utilizations of a device with SAW is in scope to materials that experience an adjustment in measurement or mass within the sight of a phenomenon.

Thus the author in [8] concludes that the correct information of the important configuration parameters and material choices affect the assembling and sensor operation. SAW sensors are intended to satisfy the detecting numerous applications. As interest for detecting advances (and specifically, dispersed, remote detecting systems) builds, hope to view the utilization and scope of uses of sensors using SAW to increment too.

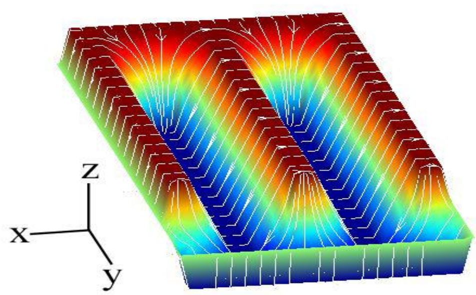

Figure13: Voltage and Electric Field Characteristics [8]

The author in [9] articles about the SAW based gyroscope using $LiTaO_3$ substrate. The SAW gyroscopic impact can be explored by assigning a successful permittivity technique with an administration of little proportions to the speed of rotation and SAW frequency. The hypothetical examination shows that a larger shift in velocity was seen from the pivoted substrate of X-112°Y $LiTaO_3$. In that point, two reverse course SAW delay lines and an 160 MHz operation frequency are manufactured on an equivalent chip of X-112°Y $LiTaO_3$ as an input of two SAW oscillators, that go about as sensor component. The Single Phase Unidirectional Transducer (SPUDT) and brushed transducers are utilized for delay lines structure to enhance frequency steadiness of oscillator. Subsequently, the assessment of the sensor execution in the interim, the differential structure was executed to two fold the sensitivity and make up for temperature impacts. Utilizing an exact rate table, the execution of the manufactured SAW gyroscope was assessed tentatively. A great linearity is watched. Thus, the author concludes that the figured results show that among normal substrates of piezoelectric, a bigger sensor reaction was seen from the rotated X-112°Y LiTaO3and the linearity was acquired.

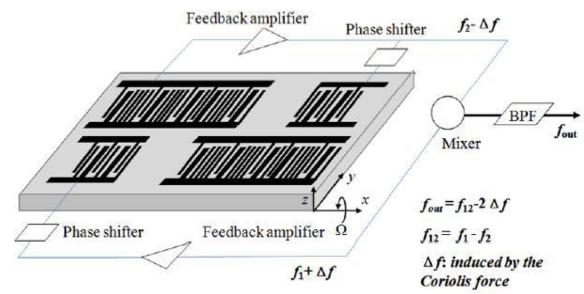

Figure 14: SAW Gyroscope

The author in [10] provides a study on SAW vibration sensor; these types of sensors are used in electronic warning system, where the setup is collected from linked structure of SAW vibration in view of a delay line SAW fabricated over piezoelectric plate surface. The plate vibrations are changed to electric signals that permit sensor identification and limitation of a risk. The hypothetical investigation on vibrations of sensors drive straightforwardly isotropic model with one level of opportunity. This model permitted an express depiction of the plate of sensor development and recognizable proof of the sensor vibrating. Examination of frequency reaction of the sensor plate made of ST-cut quartz and a damping rate of its motivation reaction has been directed. The examination above the premise to decide the scopes of vibrating plates parameters that are valuable in electronic

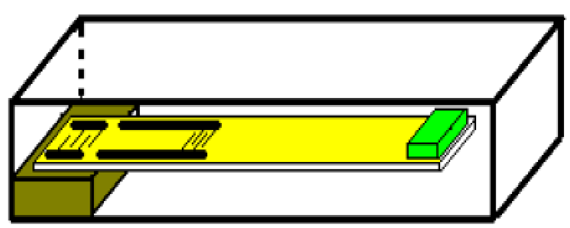

Figure 15: Structure of SAW Vibration Sensor

VII. CONCLUSION

In this paper, the actual designing of SAW sensor technology has been reviewed. A survey of the parameters was given, which is necessary for the design of an actual sensor system.The author in [2] of this paper suggested the use of SAW devices for passive wireless sensors, where these type of radio sensors make it conceivable to peruse estimation at remote areas by considering its values. The author also compared various type of SAW sensors (reflective delay line, resonators and dispersive) and their equations for sensitivity calculation. The author in [3] defined an application where the

SAW sensors were used to monitor the tire pressure in cars/road vehicles and this monitoring is continuous as it is done at even period of driving. The author in [4] developed a remote sensing device for detection of temperature and pressure using SAW sensor. The author in [5] monitored both tire pressure and also the thread wear and temperature. Thus, the author calls it an intelligent tire. The author in [6] described the use of SAW devices in harsh environment and also provided the information on oxygen gas sensor implementation. The author in [7] defined the designing and fabrication of the transducer in SAW sensor using the conventional lithography technique. The author in [8] concluded that the correct information of the important configuration parameters and material choices affect the assembling and sensor operation. The author in [9] concluded that among normal substrates of piezoelectric a bigger sensor reaction was seen from the rotated X-112°Y $LiTaO_3$ and the linearity was acquired. The author in [10] provided a study on SAW vibration sensor; these types of sensors are used in electronic warning system.

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