SAW Biosensor using PVDF Thin Film and ZnO Nano-particles

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***Abstract* —Surface Acoustic Wave (SAW) sensors, as a class of Micro Electro Mechanical Systems (MEMS), are widely used recently. The sensor can transform an input electrical signal into a mechanical wave which can be easily influenced by physical phenomena. Then, the changed mechanical wave is transduced back into an electrical signal. The presence of the desired phenomenon can be detected through the difference between the input and output electrical signal (amplitude, phase, frequency, or time delay). The basic surface acoustic wave device consists of a piezoelectric substrate, an input Inter-Digitated Transducer (IDT) on one side of the surface of the substrate, and a second output IDT on the other side of the substrate.**

***Keywords*—MEMS Sensors, IDTs, Piezoelectric sensors, SAW devices, Rayleigh wave, Polyvinylidene fluoride, Sol-gel process.**

I. INTRODUCTION

Sensors are the devices that have become so inevitable that they are a integral part of our lives, any person in the present day knowingly or unknowingly is completely reliable on these devices to gather information of the environment and overcome the any danger, these devices are widely used in most of the portable devices, automobiles, electrical appliances, space craft's and air craft's, mobile phone these days use the accelerometer for measuring linear acceleration and gyroscopefor measuring the angular rotational velocity they also use light sensors to optimize light and in automobiles the sensors used are accelerometer, speedometer, parking sensors and pressure sensors. Thus there is a large need for sensors that are smaller, cheaper and highly sensitive [2]. These demands can be met by MEMS due to its micro fabrication process. There are various class of MEMS sensors, for the application in this paper we focus on surface acoustic wave sensors which uses the principle of piezoelectric effect. Surface acoustic wave technology uses an IDT to convert electrical energy into an acoustic wave. The acoustic wave then travels across the surface of the device substrate to another inter-digitated converting the wave back into an electrical signal.

A biosensor can be defined as an analytical device in which a biologically active component (receptor), such as an enzyme, an antibody, etc., is immobilized onto the surface of anelectronic, opticor optoelectronic transducer, allowing the detection of target analytes in complex mixtures. Thus, advances in bio sensing can be achieved by efforts in two main fields: the transduction mechanism andthe biological reception mechanism (sensitive film). This fact makes bio sensing highlyinterdisciplinary [1].

II. THEORY OF OPERATION

These SAW devices have the IDTs excitation electrodes fabricated on the one side of the piezoelectric film.The sensor can transform an input electrical signal into a mechanical wave which can be easily influenced by physical phenomena.

Then, the changed mechanical wave is transduced back into an electrical signal. SAW devices specifically use the Rayleigh wave a transverse surface wave in operation.

The presence of the desired phenomenon can be detected through the difference between the input and output electrical signal (amplitude, phase, frequency, or time delay) [1]. As a result, the SAW devices have the acoustic waves propagating along the surface of the piezoelectric substrate. The SAW device could be resonator or delay line depending of the design of the IDTs [1]. For SAW resonators the IDTs are fabricated in a central position and reflectors are added on both sides of the input and output IDTs to trap the acoustic energy within a cavity. The surface between the IDTs is coated with antibodies sensitive to the analyte to be detected. The analyte molecules binding to the immobilized antibodies on the sensor surface influence the velocity of the SAW and hence the output signal generated by the driving electronics.

For biosensors it is necessary to take care of toxicity, reliability of the device, so in this work biodegradable and non-toxic polymer materials are used. Polydimethylsiloxane (PDMS) as a microfluidic channel, Polyvinylidene Fluoride (PVDF) as a piezoelectric material which has attracted much interest as a next-generation piezoelectric and pyro electric material because of its light weight, flexibility, low power consumption, and non-toxicity. The enhanced permittivity, which is related to the polarization and dipole moment of PVDF, is key factor for improving the piezoelectric and pyro electric properties of PVDF. For this reason, the semiconductor zinc oxide (ZnO) is of interest, as it increase the piezoelectric response, is thermally stable, and may increase the permittivity of PVDF. Therefore, a hybrid PVDF matrix with a Znonanofiller may enable fabrication of a hybrid piezoelectric/pyroelectric sensor. Here we report a highly sensitive hybrid functional sensor using a PVDF thin film and vertically grown ZnO nanorods. The morphology of the ZnO nanostructures was controlled to maximize the response of the device. PVDF thin film is prepared using PVDF granules and

Znonano particles (nanorods) were prepared using Zinc acetate dihydrate $Zn(CH_3COO)_2H_2O$. From sol-gel process. IDT's are printed on PVDF polymer,using screen printing methods.

III. DESIGN METHODOLOGY

In order to design the biosensor we need to know the desired antigen and the necessary anti-body. initially the ac input is applied to the input IDT which passes through the piezoelectric material by electrical to mechanical conversions and then the waves propagate on the surface of the biosensor when the anti-body detects the desired antigen the waves that were propagating will have a change in the phase, amplitude and frequency then these mechanical waves are converted into the electrical signal using the output IDT.

This paper is carried out for an application, where in there is a requirement to sense the desired antigen due to change in phase amplitude and frequency.

The IDT's shown here are of delay line configuration, i.e. the acoustic wave propagates along the surface of the material butis received at the output IDT after a certain delay.

There are various factor that are to be considered, these factors depend on the application, such as size, efficiency and sensitivity.Before determining the parameters for a specific surface acoustic wave sensor design, several important device characteristics must be specified. Among these characteristics are the physical size, bandwidth, operating frequency, impulse response, and frequency response of the device [2].

1) Rayleigh wave: These are the waves that were predicted by Lord Rayleigh in 1885, these waves propagate along the surface of the device at the speed of 3996 m/s,this wave has the capability to conserve the energy and also to travel along the surface of the material farther than any other waveforms.

This biosensor was designed to operate at 433MHz, so the wavelength is given by

$$\lambda = \text{Rayleigh wave/ target frequency} \quad (1)$$

2) Synchronous Frequency fo: The synchronous frequency fo of the device is the frequency f of the generated surface acoustic wave in a normal environment. The important parameters in determining the synchronous frequency of the device is the pitch p of fingers of the IDTs [4], were the fingers are placed at equal intervals. These consecutive fingers are equal but of opposite polarity [4].

$$fo = Vp/ p \quad (2)$$

where, Vp is the propagating velocity

Figure 1 shows the general structure of the biosensor with the piezoelectric material being PVDF and Zno to increase the piezoelectric effect.

Figure 2 shows the SAW IDT design where p is the pitch

$$p = \lambda \quad (3)$$

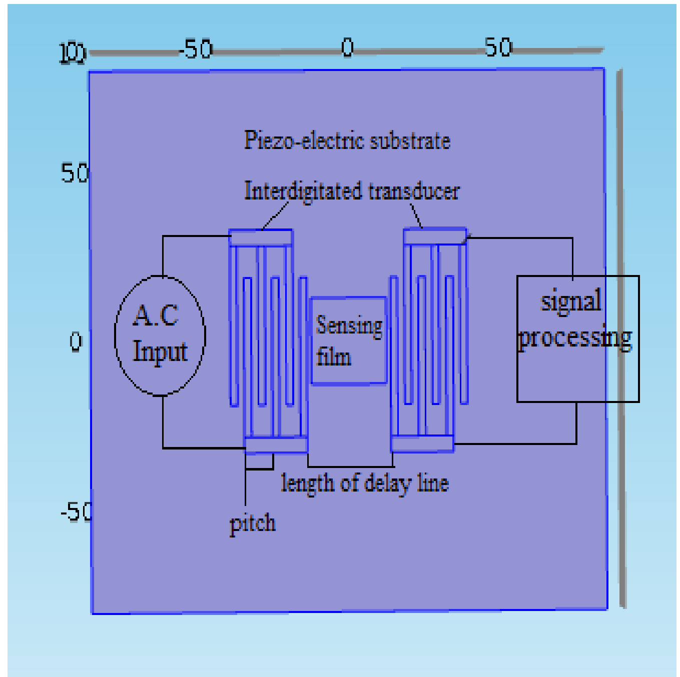

Fig 1: General Structure of the SAW Sensor

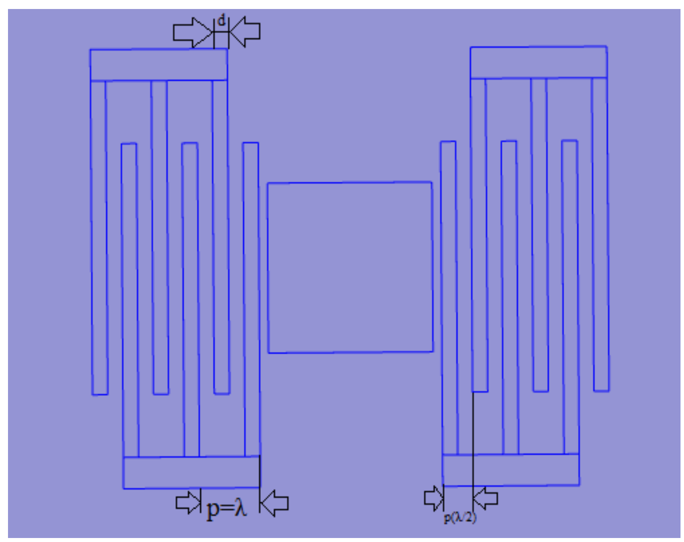

Fig 2: SAW IDT Design

IV. SIMULATION AND RESULT ANALYSIS

In this paper we are comparing two simulations of a biosensor, with and without mass on the sensing film, in the simulation we have found that there has been a variation in the output voltage plot, there has been a variation in the amplitude and also there has been a delay in the waveforms, Thus stating that when the mass is applied the acoustic wave propagating on the surface of the material will undergo amplitude and phase changes, meeting the desired result.

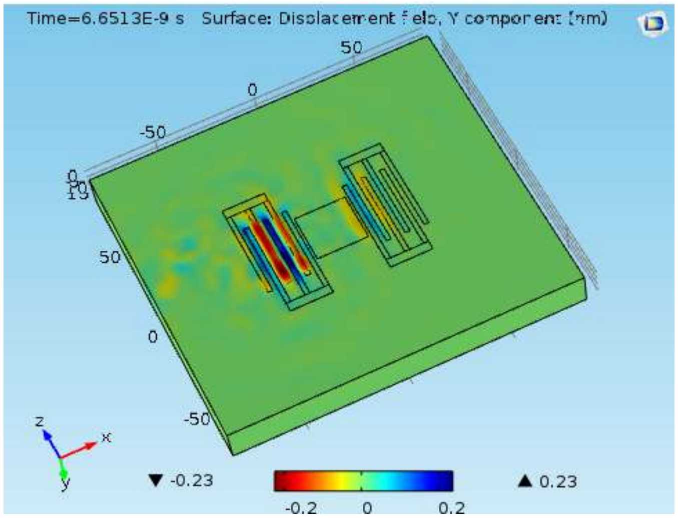

Fig 3: Displacement of SAW Biosensor without Mass

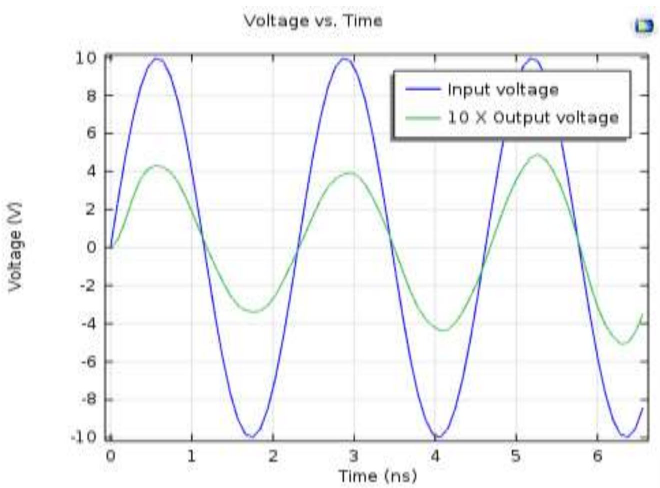

Fig 4: Input and Output Plot of SAW Biosensor withoutMass

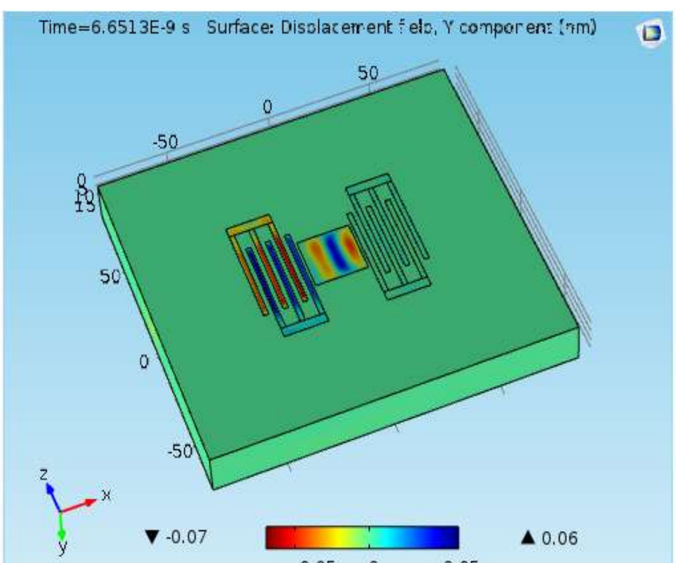

Fig 5: Displacement of SAW Biosensor with Mass

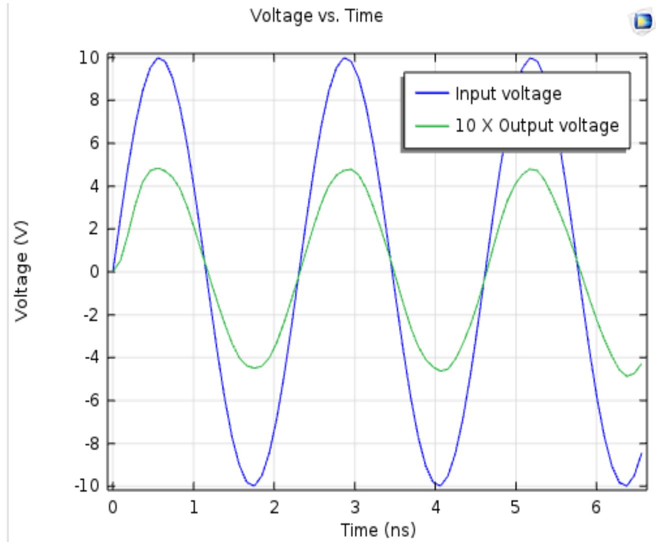

Fig 6: Input and Output Plot of SAW Biosensor with Mass

IV. CONCLUSION

The paper is based on the design of SAW Biosensor using PVDF thin film and ZnO nanoparticles which gives an insight to design and also a comparison between biosensor with and without adding mass on the sensing film thus showing a desirable change in the input and output voltage waveforms as shown in the table 1 and 2. Also there has been a change in the amplitude and phase.

The difference in the amplitude and phase at the output determine the desired mass applied on the sensing film.

V. FUTURE SCOPE

In the paper it shows only the simulation as a future work it would be fabrication of Biosensor with PVDF and ZnO, later functionalising it with desired bio anti-body which is used to detect certain anti-gen.

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