A Short Review: Design and Simulation of Surface Acoustic Wave based Sensor for Gas Sensing Application

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Abstract— Several methods have been reported for detecting gas based on surface acoustic wave (SAW) technology. In this article, designing and simulation of different SAW based sensors is reviewed. Design, modeling and simulation using COMSOL Multiphysics software are discussed to study the effective active layer and electrode arrangement to achieve enhanced resonant frequency. Several simulation reports are reviewed to understand the parameters affecting the performance of the SAW device. The sensitivity of the sensor could be improved by varying dimension of the device, thickness of the intermediate layer, and the gap between the electrodes. This paper highlights the fundamentals to modern design developments, modeling and simulation of SAW devices for gas sensing application.

Keywords— (Gas Sensor, COMSOL, Zinc Oxide, Electrode)

I. INTRODUCTION

A surface acoustic wave (SAW) is an acoustic wave which exhibits elasticity by travelling along the top of a piezoelectric substrate and its amplitude gets decreased exponentially with respect to depth into the substrate. Lord Rayleigh [1] predicted its properties and explain about surface acoustic mode of propagation. Piezoelectric materials are used to transform electrical signals to surface acoustic wave [2]. In presence of applied electrical field, piezoelectric materials become deformed. Due to this phenomenon, waves can be generated by forming comb-shaped electrodes (i.e., IDTs). To some extent the wave velocity s related with the types of substrates used. Controlling IDT, the generated wave frequency can be changed. Similarly, when surface acoustic wave arrives at the electrode, if pitch of electrode and SAW match, an electrical signal is produced between the IDT and electrode.

Figure 1. Model of Surface Acoustic Wave Sensor [4].

SAW based gas sensors are a class of MEMS which sense a physical phenomenon with modulation of SAW [3]. Here, electrical signal is converted into a mechanical wave which, can be affected by physical phenomena. So, the SAW device again converts the mechanical wave to an electrical signal.

Figure 2. 2D NanoStucture Enhanced Gas Sensor [9].

Sometimes chemical treatment is done on the surface area to make it sensitive for molecular absorption (or) adsorption. The SAW sensor can detect if molecular adsorption/absorption or viscoelastic changes occur on the sensitive surface. It operates by measuring the variation in wave characteristics e.g. insertion loss and frequency shift. To increase the active area of sensor and enhance the performance detection incorporates nanostructures [4]. In this review article, the sensing based on the wave properties such as voltage towards gases and acoustic waves displacement will be reviewed.

Figure 3. 2D Nanostucture Enhanced Gas Sensor [10].

II. MECHANISM BEHIND SENSING
To design a highly sensitive layered SAW based gas sensor device and it is important to understand the interaction between sensing layer and gas a sensing mechanism [5]. In sensing mechanisms mostly use gravimetric. Due to mass adsorption on the structure, velocity of wave may get changed. Other sensing mechanisms are based on the change in viscosity, density, permittivity or conductivity of the sensing layer [6]. Due to acoustic electric field, the mechanical wave is accompanied by a layer of bound charge and this links to electromechanical coupling coefficient (k^2) of the material [7].

III. SENSOR MODELLING AND ANALYSIS

For sensing applications, a 3D representation (shown in fig. 5) of the SAW ZnO Nanowire based gas sensor is used and it is reported by Gouthami et.al. As it is shown in Fig. 4, the piezoelectric substrate dimensions are 30µm in X-axis, represents the width of substrate, 10µm in propagating y-axis and about 4µm in z-axis. Due to limitations on number of nodes which software can generate, the dimensions are chosen. Intermediate layer of ZnO with size of 30µm in x-axis, represents width, 10µm in y-axis and about 1µm in z-axis is placed above the piezoelectric substrate. ZnO nanowires standing with size of 0.1µm as the radius and 2.5µm as the height are placed at the centre of the input and output ports. The IDTs dimensions are 1µm as width and height is 0.2µm. In COMSOL Multiphysics the simulation of SAW device are performed and analysis is done by piezoelectric studies [10]. By interfacing between the geometry, the boundary settings

IV. RESULTS AND ANALYSIS

The prime objective is to find the optimum thickness for electrodes of IDT’s. By using parametric sweep to optimize and compare the results at different electrode thickness such as 0.4µm, 0.6µm, 0.8µm, 1.0 µm respectively are shown in Fig. 7.

The simulation of voltage contour, when the sensor is exposed to target gas, bound charge of layer is produced, this results in production of electrical potential and voltage contour which is depicted in Fig. 8. Different colors observe in the simulation result (shown in Fig.6 ) due to presence of electrical potential within the layer. The higher value represents red colour and minimum or zero value represents blue colour . The blue colour in the middle of sensor represents as the electrical energy is converted to mechanical wave which doesn't have any potential. Now, at the output IDT’s, converted back to electrical energy.
The Design simulation and analysis of nanostructure based surface acoustic wave gas sensors are reviewed. Multilayer layer structure made of ZnO (upper layer) and lithium niobate is studied. Different multilayer structure are reported but ZnO-LinbO3 is found to be suitable for SAW Sensor Optimization of SAW Sensor is possible by considering different intermediate material with different dimension. From this survey is observed that the performance can be enhanced by changing thickness of the sensing layer and electrode orientation. Besides frequency shift and total displacement will also be improved. Thus SAW based gas sensor may provide enhanced performance in terms of sensitivity.

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