Simulation of ZnO Enhanced SAW Gas Sensor

H. du Plessis[1], W. Perold[1]

[1]University of Stellenbosch, Stellenbosch, South Africa

Abstract

Gas sensors are part of our everyday life and have uses in the medical field for diagnoses, industrial field for safety precautions, research applications, etc. With the increased use of nanotechnology over the years and most devices going towards the nanoscale there is an ever growing need to further increase the sensitivity of these sensors. With the help of micro-electro-mechanical systems (MEMS) and nanomaterials to create surface acoustic wave (SAW) devices, sensors capable of measuring at that level of sensitivity can be created.

A two-pot delay-line configuration is best suited for gas sensing capabilities. In such a configuration a set of interdigital transducers is used as input and output for the device. These metal transducers are placed on top of a piezoelectric substrate to generate and receive the acoustic waves. In this study aluminium is used for the transducers and 128YX lithium niobate for the substrate. The mass loading effect at the sensing area of the SAW device makes it possible to measure characteristic changes such as frequency shifts and insertion loss. The addition of a nanomaterial on top of the sensing area further increases the sensitivity of the sensor. For this study zinc oxide nanopillars are used as the nanomaterial.

COMSOL Multiphysics® is used to simulate, investigate and optimise the SAW sensor. Using the Piezoelectric Devices physics a cross section of the substrate and transducers, as seen in Figure 1, is simulated. A Frequency Domain Study is applied to the model to find the resonant frequency, as seen in Figure 2, of the device. Using this setup parametric sweeps can easily be implemented to find an optimised sensor by varying the transducers' thickness, the number of electrodes per transducer, the addition of reflectors and their quantity. Furthermore a Time Dependent Study is run where an impulse is used as input into the transmitting transducer. From the results the insertion loss of the device can determined. By adding zinc oxide nanopillars to the sensing area the characteristic changes can also be observed.

From the simulations it can be seen that the resonant frequency is where it was theoretically calculated to be. Furthermore the optimal total displacement in the substrate reaches a maximum with a transducer height of 200nm. With this sensor configuration it is also noticed that the minimum insertion loss is obtained when the delay line is approximately one wavelength. Of course this also puts a boundary on the size of the sensing area. Using four electrodes per transducer together with three reflectors on either sides of the sensor also has a positive effect. The final result still to be obtained is the addition of a gas or pressure on the sensing area and the effect thereof on the sensor.

The results from the simulations show great potential and there is even room for additional components to be added later such as membrane layers and wireless technology. All the simulation results will be verified by the physical fabrication of the sensor and comparison of the

theoretical versus the practical.

Reference

1. Guanshui Xu, Direct finite-element abalysis of the requency response of a Y-Z lithium niobate SAW filter, Smart materials and structures, vol. 9, no. 6, pp. 973, 2000
2. S. Ahmadi et al., Characterization of multi-and single-layer structure SAW sensor, Sensors, Proceedings of IEEE, pp. 1129-1132, 2004
3. Guigen Zhang, Nanostructure-Enhanced Surface Acoustic Waves Biosensor and Its Computational Modelin, Journal of Sensors, vol. 2009, 2009
4. M.Z. Atashbar, A.Z. Sadek, et al, Layered SAW gas sensor based on CSA synthesized polyaniline nanofiber on AlN on 64° YX LiNbO< sub> 3 for H< sub> 2 sensing, Sensors and Actuators B: Chemical, vol. 138, no. 1, pp. 85-89, 2009

Figures used in the abstract

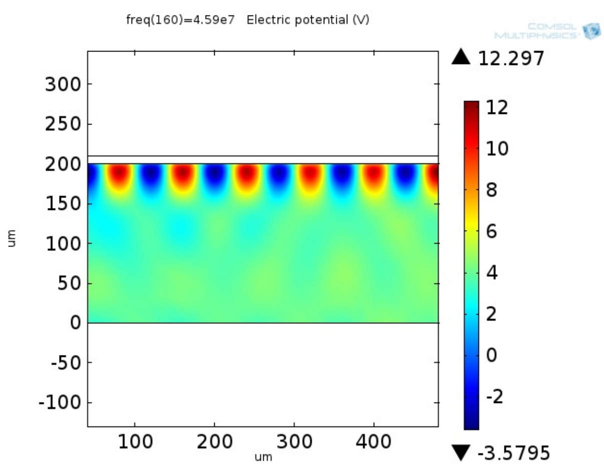

Figure 1: Cross section of sensor with SAW at resonant frequency

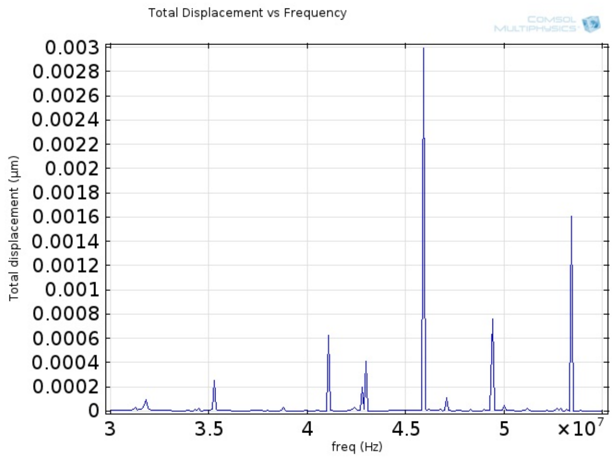

Figure 2: Frequency sweep of sensor showing resonant frequency at 45.9MHz