Piezoelectric bacterial sensor design using simulation tools.

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Introduction

- A biosensor is a a device that uses specific biochemical reactions mediated by isolated enzymes, immunosystems, tissues, organelles or whole cells to detect chemical compounds usually by electrical, thermal or optical signals [1].
- Quartz Crystal Microbalance, Surface Acoustic Waves(SAW) and Piezoelectric Cantilevers are one of the best choices for the measurement of biological agents.
- The different SAW devices like Shear Horizontal-SAW, Love Wave and SH-Acoustic Plate Mode had proven high efficiency working with liquid samples (Fig. 1).

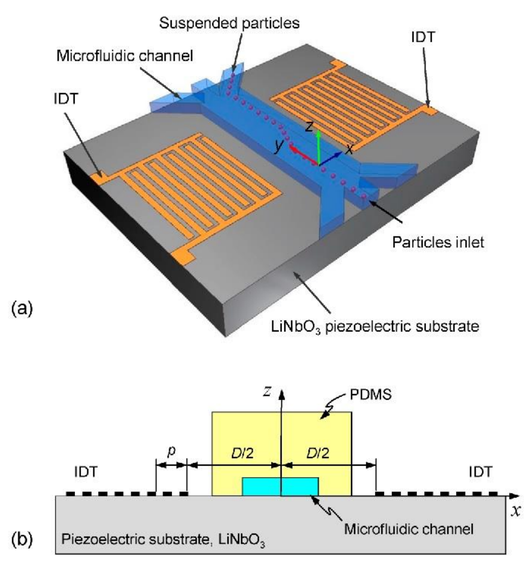

Fig. 1: SAW sensor Delay line

Design and fabrication challenges of a piezoelectric device

- The right choice of the materials for the piezoelectric substrate and the interdigital transducers (IDT).
- High cost of the manufacturing techniques.
- Optimitation of resources and design parameters for the best performance.
- Eliminate or reduce second order effects.

Biological detection method

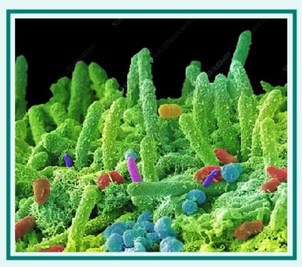

Fig. 2: Pathogenic microbial agent.

Fig. 3: Radial immunodiffusion technique in petrish dish.

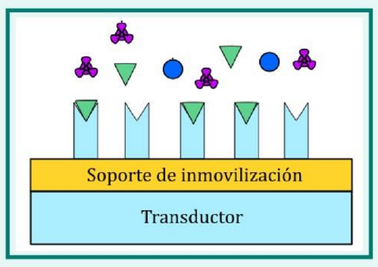

Fig. 4: Biorecognition for a specific analyte.

The traditional methods are Microbial culture, Enzyme-linked immunosorbent assay (ELISA), Polymerase chain reaction (PCR), etc.

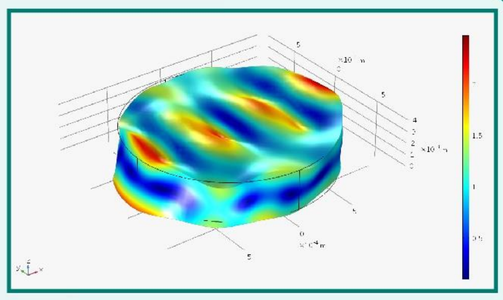

Fig. 5: Eigenfrequency analysis of the Quartz Crystal Microbalance.

References

[1] D. R. Thévenot, K. Toth, R. A. Durst, and G. S. Wilson, "Electrochemical biosensors: Recommended definitions and classification," Biosens. Bioelectron., 2001, doi: 10.1016/S0956-5663(01)00115-4.

[2] Arnau, A. (Ed.). (2004). Piezoelectric transducers and applications (Vol. 2004). Berlin: Springer

[3] C. S. Hartmann, D. T. Bell and R. C. Rosenfeld, Impulse model design of acoustic Surface-wave filters, IEEE Trans Microw Theory Tech, 21, pp. 162-175, 1973.

Piezoelectric transducer

- Eigenfrequencies.
- Energy dissipation.
- Mass sensitivity.

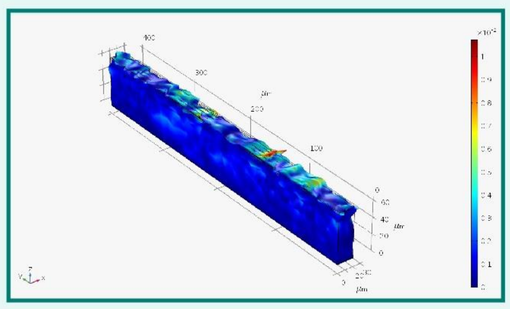

Fig. 6: Eigenfrequency analysis of the SH-SAW in a LiNbO3 substrate with 128° YX orientation.

Preliminary transducer model response

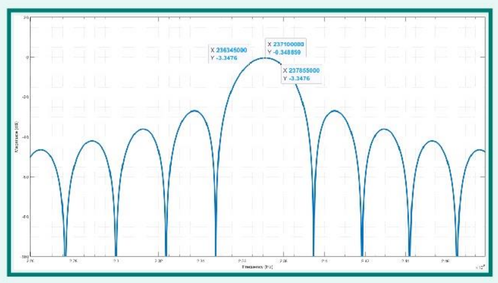

Fig. 9: Frequency response H(f) of the SAW IDTs with an electrode width of 5μm.

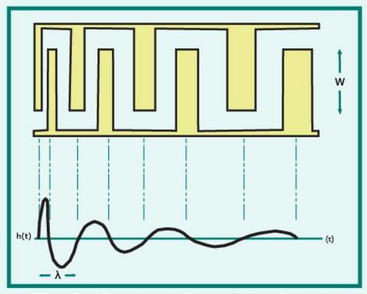

Fig. 8: Construction of the impulse response of a uniform overlap IDT.

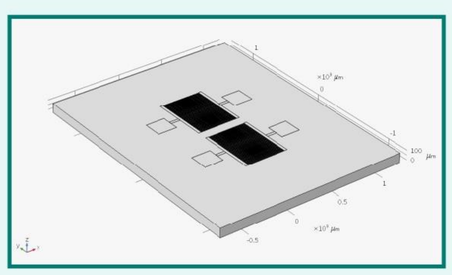

Fig. 7: Piezoelectric biosensor geometry.

The results were obtained using COMSOL and MATLAB simulation tools.

Conclusions

- Choosing the right immobilization technique for the sensitive area is critical.
- The effect of the crystal orientation influences the piezoelectic properties such as the field direction.
- The frequency response of the interdigital transducers shows the main features of the passband for sensor design.
- Computational tools enhance the undestanding of complex systems.

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Future Work

- Improve biosensor design parameters in order to enhance sensibility and specificity.
- Fabrication of the SAW device
- Characterize biosensor with flow-through and dip-and-dry tests.
- Circuit design for the biosensor signal conditioning.