3P3-9

Study on optimization of shear horizontal surface acoustic Wave sensor structures using finite element method

Yudai Ota[1†] and Jun Kondoh[1, 2*] ([1]Grad. School of Integrated Science and Technology, Shizuoka Univ.; [2]Grad. School of Science and Technology, Shizuoka Univ.)

1. Introduction

Shear horizontal surface acoustic waves (SH-SAW), which propagate by concentrating energy on a piezoelectric crystal surface, are perturbed by physicochemical changes in the medium in contact with the propagating surface. By utilizing the change in propagation characteristics caused by the perturbation, a sensor for the viscosity, density, dielectric constant, and conductivity of the medium can be realized. In previous research, numerical analysis and perturbation methods have been used to evaluate SH-SAW sensors[1). These methods are difficult to evaluate for sensor structures. If the evaluation with a finite element method (FEM) model becomes possible, the optimization of the sensor structure will become easier. This paper describes the validity of the evaluation of SH-SAW sensors using FEM models in comparison with numerical analysis methods.

It has been reported that a SAW resonator with a high coupling coefficient can be obtained by using a bonded structure of 36YX-$LiTaO_3$ and AT-cut quartz[2). It is expected that the same structure can be used for delay-line SAW sensors with a high coupling coefficient and high sensitivity. Therefore, we analyzed the LT/Quartz structure by FEM and compared the sensor sensitivity with that of a single LT structure.

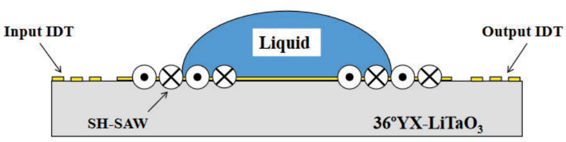

Fig. 1 Schematic illustration of the SH-SAW propagation at a liquid/solid interface

kondoh.jun@shizuoka.ac.jp

2. SH-SAW sensor and evaluation

SH-SAW sensors consist of two comb-shaped electrodes (IDTs) on a piezoelectric crystal to which an AC signal is applied. The space between the IDTs is the propagation plane, which is loaded with a metallic film when measuring the density or viscosity of the medium. **Fig. 1** shows the structure of the SH-SAW sensor. The phase at the resonance frequency changes when the film thickness is varied due to the mass loading effect, which is a mechanical perturbation, and thus the propagation velocity of the SH-SAW can be varied.

The model of the SH-SAW sensor was created using FEM software. IDT electrodes were fabricated with gold on 36YX-$LiTaO_3$. The spacing of the electrodes was designed so that the resonance frequency is 155 [MHz]. First, 200 [nm] of Au was loaded on the propagation surface as a reference. Harmonic analysis was performed on the model to obtain the S-parameters, amplitude, and phase. FEM analysis was performed by changing the gold thickness to 210, 230, 250, 300, and 400 (nm), and the phase difference from the reference was obtained. The velocity change was calculated from these values.

Numerical analysis of SH-SAW was carries out based on the classical methods proposed by Campbell et al.[3) and Yamanouchi, et al.[4) Numerical analysis was performed on the same model using the FEM analysis. The phase velocities of SH-SAW were obtained for each film thickness. **Fig. 2** shows the comparison results of the velocity change, $\Delta V/V$, as a function of gold film thickness obtained by the both methods. The velocity changes for the two methods agree well.

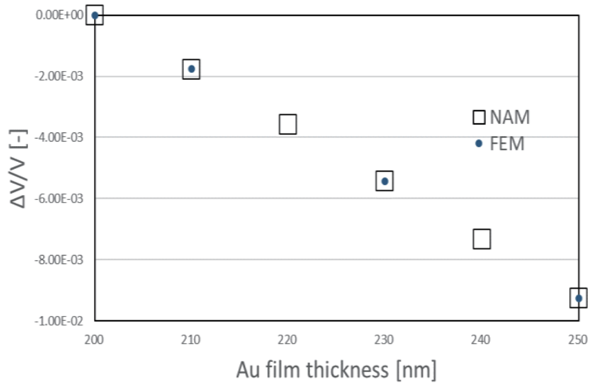

Fig. 2 Velocity change as a function of gold thickness

3.Examination of LT and Quartz bonded Structure

From the previous section, it was confirmed that SH-SAW sensors can be evaluated by FEM. The SAW resonators on a 36YX-$LiTaO_3$/AT90°X-quartz bonded structure has a high electromechanical coupling coefficients[4] It is expected that the high sensitivity can be obtained by using this structure in a delay-line SAW sensor. Therefore, a model of a SAW sensor with a 36YX-$LiTaO_3$/AT90°X-quartz bonded structure was created using FEM software and analyzed. **Fig. 3** shows an overview of the model. **Fig. 4** shows an enlarged view of the IDT and the propagation path.

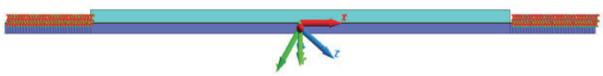

Fig. 3 overview of the model

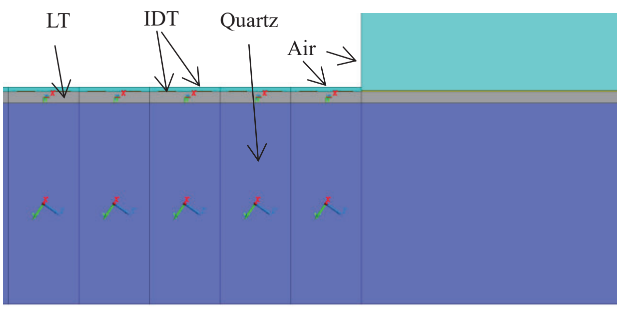

Fig. 4 Cross section of the IDT and the propagation path

The sensor model was consisted of an input IDT, an output IDT, and a propagation path (See Figs. 3 and 4). 36YX-$LiTaO_3$ piezoelectric layer is formed on an AT90°X-quartz substrate. As in the analysis of the LT single structure, the velocity change was calculated by varying the thickness of the gold film between 200 and 400 nm. The obtained velocity change for each film thickness is shown in Fig. 5. The velocity change for a single LT structure is also plotted on the figure for comparison. The figure indicates that the absolute vale of slope for the 36YX-$LiTaO_3$/AT90°X-quartz bonded structure is larger than one for single LT structure.

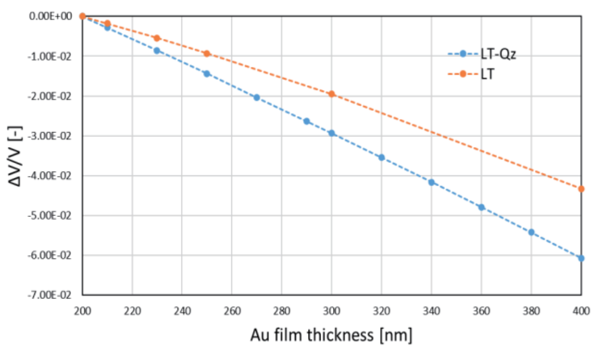

Fig. 5 Velocity change in bonded structure

4. Conclusion

From the results obtained in this study, it is clarified that the SH-SAW sensor can be evaluated by FEM. The 36YX-$LiTaO_3$/AT90°X-quartz bonded structure was analyzed using FEM, and it was found to be more sensitive than the single LT structure. In future work, we will continue to optimize the highly sensitive sensor structure.

References

1) J. Kondoh, Elect. & Comm. in Jpn., vol. 96, No. 2, p. 41 (2013).
2) J. Hayashi, K Yamaya, M Suzuki, S Kakio, H Suzaki, T Yonai, K Kishida, J Mizuno Jpn. J. Appl. Phys. **57**, 07LD21 (2018).
3) J. J. Campbell and W. R. Jones, IEEE Trans Sonics and Ultrason., Vol. SU-15, p. 209 (1968)
4) K. Yamanouchi and K. Shibayama, J. Appl. Phys, Vol 43, p. 856(1972)