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Comparison of SH-SAW sensor sensitivity based on gold nanoparticle deposition

金微粒子吸着法による横波型弾性表面波センサの感度比較

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1. Introduction

Important application of acoustic wave sensors is a biosensor for detecting immunoreactions. Shear horizontal surface acousitc wave (SH-SAW), Love wave, and thickness shear mode (TSM) devices have been used for this purpose[1]. As a detection mechanism of the immunoreaction is mechanical perturbation, sensor sensitivity increases with frequency. This means that high frequency sensor has higher sensitivity. Therefore, high sensitive biosensor will be required by using the SH-SAW and Love devices[2].

When the sensitivity of the SH-SAW and Love wave sensors is compared at a constant frequency, it depends on sensor structures, namely piezoelectric substrate and wage guide materials. Therefore, to find optimum configuration of the sensor structure is needed. In this paper, first, we numerically compare the sensitivity. Then, comparisons on the basis of experimental results are carried out. For experimental comparison, gold nanoparticles are deposited on the sensor surface[3].

2. Numerical calculation

Coordinate system in this study is shown in **Fig. 1**. The SH-SAW devices are constituted from a piezoelectric substrate and wave guide layer. **Fig. 2** shows the calculate phase velocity of the SH-SAW in the gold/piezoelectric substrate structure as a normalized thickness of the wave guide. Slope of the velocity indicates the mass sensitivity. It is found that the magnitude of slope for 41YX-LiNbO$_3$ is the highest in the three substrates. However, for 41YX-LiNbO$_3$, the velocity is not obtained when thickness increases.

3. Experimental

In this study, we used three piezoelectric substrates of 36YX-LiTaO$_3$, 64YX-LiNbO$_3$, and 41YX-LiNbO$_3$. Propagation waves of those substrates are the SH-SAW. **Fig. 3** shows schematic diagram of the sensor configuration. Center frequency of the used sensors is 51 MHz. Propagating surface is electrically shorted by using gold evaporated film. Gold thicknesses on 41YX-LiNbO$_3$ and 64YX-LiNbO$_3$ are 20 nm and it on 36YX-LiTaO$_3$ is 200 nm. The SH-SAW sensors on 41YX-LiNbO$_3$ and 64YX-LiNbO$_3$ were fabricated by us. The SH-SAW sensor on 36YX-LiTaO$_3$ was from Japan Radio Co. Ltd.

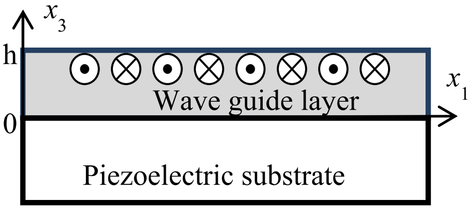

Fig. 1. Coordinate system in this study.

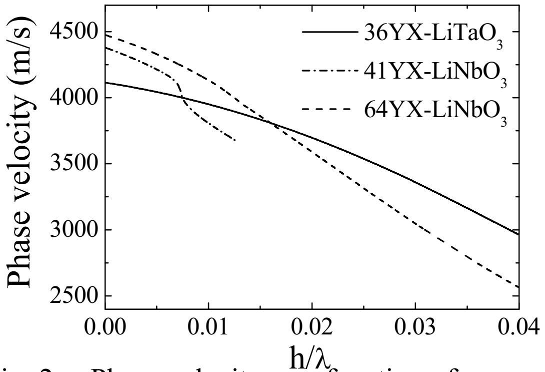

Fig. 2. Phase velocity as a function of wave guide thickness.

Gold colloid (Aldrich, G1527, 10 nm) of 5 μl was placed onto the SH-SAW propagating surface. Gold nanoparticles in the colloid were deposited onto the surface due to solvent volatilization. Phase shift before and after gold deposition was monitored by using network analyzer (Agilent, E5070B).

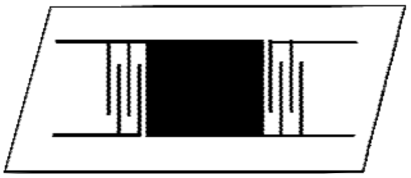

Fig. 3. Schematic of the SH-SAW sensor.

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4. Results and discussion

Experimental results are shown in **Fig. 4**. As an interdigital transducer (IDT) was used for the SH-SAW sensors on 41YX-LiNbO$_3$ and 64YX-LiNbO$_3$, phase distortion exists. However, as a floating electrode unidirectional transducer (FEUDT) is used for SH-SAW sensor on 36YX-LiTaO$_3$, phase distortion is reduced. From the figures, we compared phase shift by gold nanoparticle deposition onto the SH-SAW sensing surface. It is clear that the phase shift of 36YX-LiTaO$_3$ is the smallest in three sensors. Phase shift for 41YX-LiNbO$_3$ and 64 YX-LiNbO$_3$ are almost the same. Perturbation equation for the mass loading effect is expressed as following equation.

$$\frac{\Delta V}{V} = -A\rho h f \qquad (1)$$

Here, $\Delta V/V$ is velocity shift which is derived from phase shift, ρh is surface mass density, f is frequency and A is material dependent coefficient. In Table 1, the coefficient is shown[4]. The coefficient of 41YX-LiNbO$_3$ is the highest. This agrees with the numerical calculation results. However, from the experiments, the phase shifts for 41YX-LiNbO$_3$ and 64YX-LiNbO$_3$ are almost the same.

5. Conclusion

In this paper, mass sensitivity is discussed. Numerical method and gold nanoparticle deposition method were examined. As the gold nanoparticle deposition method is simple and reproducible, it is useful method for comparison of mass loading sensitivity. Moreover, it is possible to evaluate amount of loaded by using a scanning electron microscopy and localized surface plasmon resonance. The mass sensitivity is a function of wave guide thickness. Comparison with different thickness is future work.

Acknowledgment
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References

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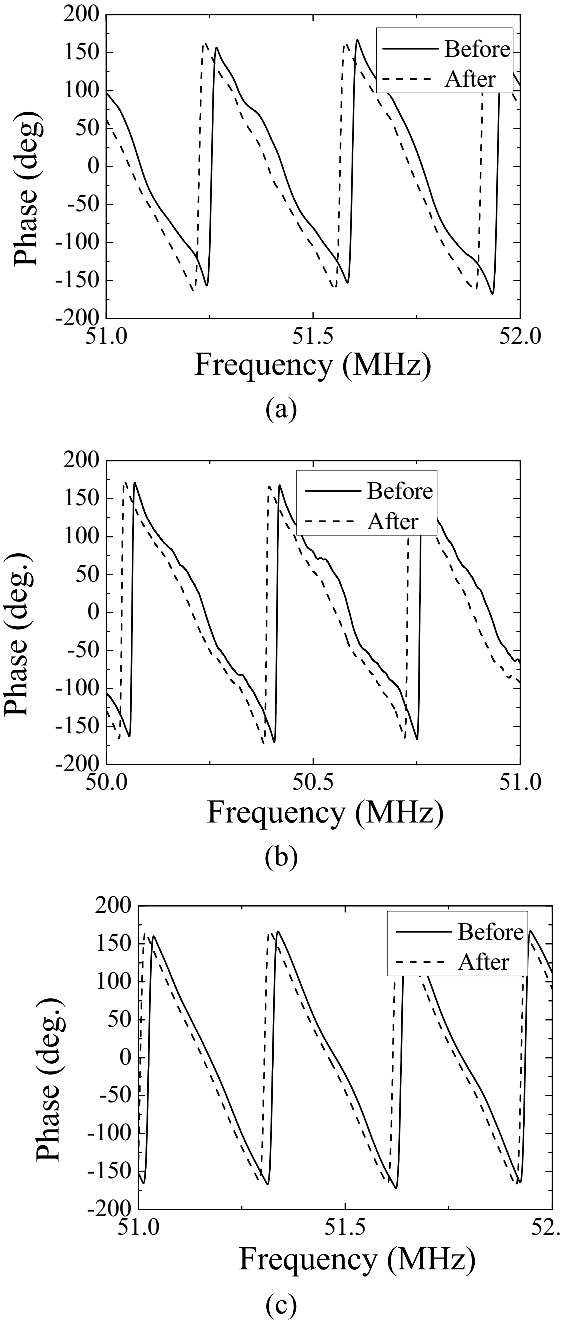

Fig. 4. Comparison of mass sensitivity before and after depositing gold nanoparticles.(a) 41YX-LiNbO$_3$, (b) 64YX-LiNbO$_3$, and (c) 36YX-LiTaO$_3$.

Table 1. Coefficient A in eq. (1).

41YX-LiNbO$_3$	64YX-LiNbO$_3$	36YX-LiNbO$_3$
7.45×10^{-9}	6.34×10^{-9}	5.30×10^{-9}