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Identification method of wireless SAW sensor based on mass loading effect

質量負荷効果に基づくワイヤレス SAW センサ認識法

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1. Introduction

A wireless sensor can be realized by using surface acoustic waves (SAW) [1]. Also, an impedance-loaded SAW sensor combined with an impedance variable sensor has been studied [1, 2]. When multi-point measurement with existing sensors are performed, the number of wires required is more than twice the number of sensors. However, replacing those with wireless SAW sensors eliminates the need for wiring.

The aging of bridges over 50 years old has become a serious problem in recent years. Therefore, structural health monitoring (SHM) is required. We have applied the impedance-loaded SAW sensor for the SHM[2]. As multi-point measurements are required, identification of the SAW sensors is important. Whereas the SAW sensors are identified based on the response amplitude of the reflector electrodes[1], there are problems such as multiple reflections between electrodes, and the amplitude of the time response depending on the distance between the antennas. Therefore, in this study, we focused on the identification based on the phase in place of the amplitude.

In this study, we propose an identification method based on the mass loading effect (**Fig. 1**). Simulation results using the perturbation theory indicated the possibility of the identification with the loaded mass[3]. In this paper, for experimental verification, we measured and examined the phase change and propagation time change caused by adding a gold layer on the SAW propagation surface.

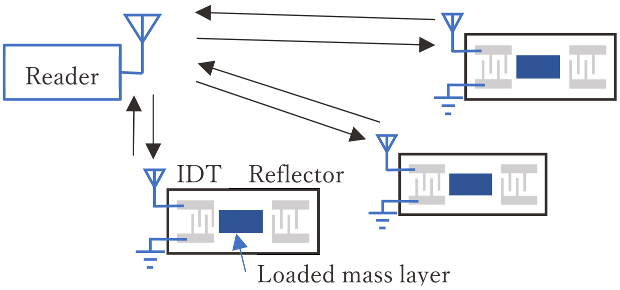

Fig. 1 Schematic of identification method.

2. Measuring method

A 50 MHz SAW device was created using 128YX-LiNbO$_3$. A gold film was loaded between the interdigital transducers (IDT), and evaporation was repeated multiple times and measurements were taken each time. The film thickness is calculated from the film thickness of 250 nm measured using a surface profiler (Alpha-Step IQ) and the gold deposition amount. The experimental system used in this study is shown in **Figs. 2** and **3**. A continuous wave was used for the phase change measurement, and the phase change between the input and output signals was measured as the time difference. The propagation time was measured using a burst wave. In this experiment, four devices were measured under the same conditions. Since this study was a feasibility experiments, all experiments were carried out with the wired connection.

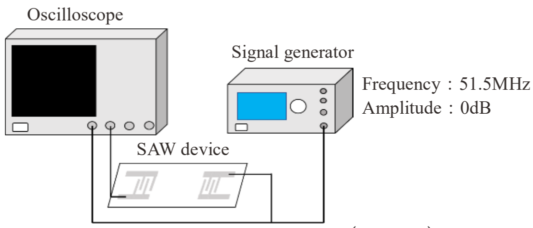

Fig. 2 Experimental system（Phase）

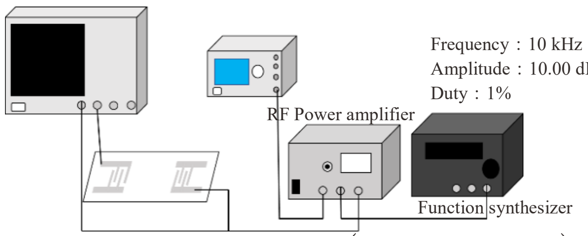

Fig. 3 Experimental system（Propagation time）

3. Results and discussion

Fig. 4 shows the absolute value of the phase change before and after the gold film deposition on each substrate. From Fig. 4, it is confirmed that the phase change increases with increasing film thickness for all substrates. The variations in the results for each device are due to the variation of the evaporated gold thickness, because it depends on the position in the evaporation system. It is clarified that the SAW sensor can be identified by using the phase change even with a small film thickness.

On the other hand, in SAW propagation time measurement using the system in Fig. 3, no change in propagation time due to mass loading was observed even when the film thickness was increased (**Fig. 5**). The reason is that the change of the SAW velocity is small and the change of propagation time

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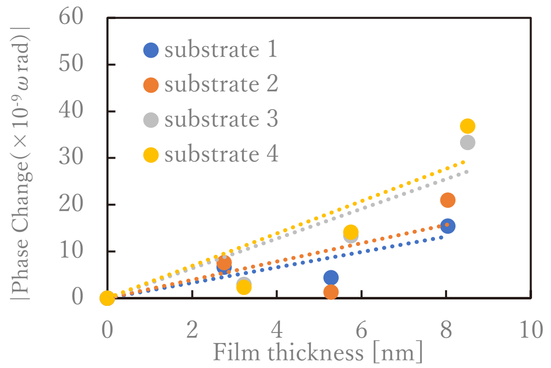

Fig. 4 Phase difference fluctuation

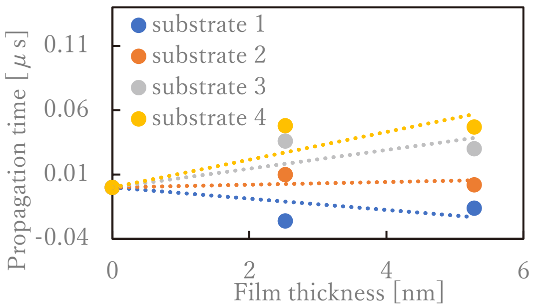

Fig. 5 Propagation time fluctuation

was not observed by the measurement system. Therefore, the phase change measurement method is suitable. It was also found that when the film thickness was increased to about 250 nm, the change in SAW propagation time increased with the film thickness (**Fig. 6**). These results show that the SAW device can be recognized using the mass loading effect.

Using the results of SAW propagation time measurements at large film thickness, we estimated the changes in the propagation time for thin gold film. Then the phase change was estimated from the burst signal measurements. **Fig. 7** shows the changes in phase over the time of measured, estimated, and calculated results. The calculated results were obtained from the perturbation equation for the mass loading effect. The estimated and measured results do not agree with the perturbation theory, when the gold film thickness increases. The tendency agrees with the differences between the perturbation and exact solutions. Therefore, reasonable results were obtained.

4. Conclusion

In this study, the gold layer was formed on the SAW propagation surface of a SAW device. Measurements of phase change and SAW propagation time at the different film thickness were carried out. For the phase change measurements, the phase change increased as the film thickness increased. For the SAW propagation time measurements, the change of the propagation time was not observed at the thin gold layer thickness. At the case of the thick gold layer thickness, the propagation time change was measured. The validity of the experimental results was shown by comparing the measurement results with the perturbation solution. We concluded that the identification of SAW sensors is possible based on the mass loading.

In future works, development of an identification method using phase change and the propagation time is required. It is important to clarify how many SAW devices can be identified by using the mass loading effect. Also, development of an evaluation method for an impedance-loaded SAW sensor at the same time is necessary.

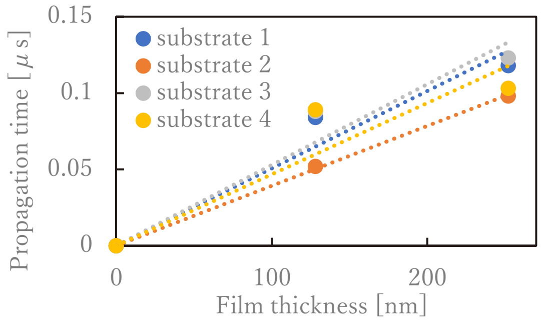

Fig. 6 Propagation time as a function of gold film thickness.

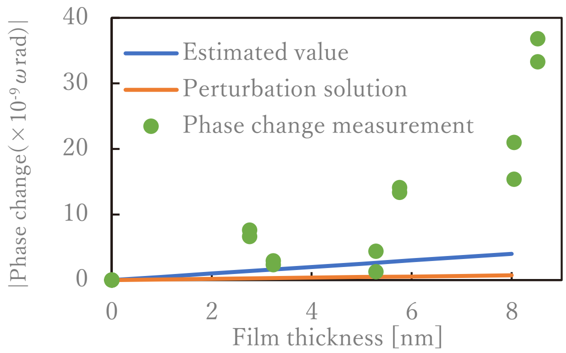

Fig. 7 Comparison of results

Acknowledgments

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References

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