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Proceedings of Symposium on Ultrasonic Electronics, Vol. 33 (2012) pp. 69-70
13-15 November, 2012

Combination of a surface acoustic wave device and classical sensor for detecting physical quantity 2- Detection of strain by using force sensor -

弾性表面波素子と物理量センサを組合せた物理量計測 2-力センサを用いたひずみ計測-

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1. Introduction

Surface acoustic wave (SAW) devices using a piezoelectric clystal have been applied to not only filters but also sensors and actuators[1-4]. In this paper, we propose a measurement system in combination of a SAW device and a classical sensor for detecting physical quantity. The measurement system has advantages of no power supply and electric circuit at sensors. The system greatly simplifies usual measurements. In this paper, as a classical sensor, a force sensor is used to estimate the starin.

2. Principle of measurement

The measurement system with the SAW device and classical sensor is shown in **Fig. 1**. An RF signal is transmitted from the network analyzer to the interdigital transducer (IDT) on the SAW device. The SAW is propagated by inverse piezoelectric effect and reflected by the reflector on the SAW device. The reflected SAW are reconverted into the RF signal by the IDT. This signal is transmitted to the network analyzer and the reflection response is measured. We evaluate S11 of scattering parameter. Reflection characteristic of the reflector depends on impedance that is connected to the reflector. By connecting the classical sensor which impedance changes by physical quantity to the SAW device and evaluating S11, we can measure physical quantity without power supply and electric circuit at sensors.

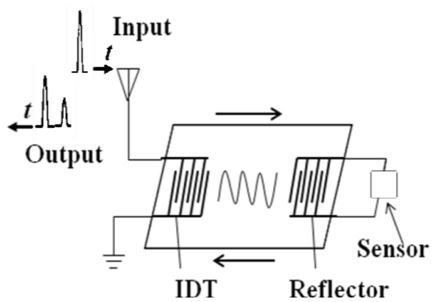

Fig. 1 Combined SAW device and classical sensor

3. SAW device and measurement system

We used a 128° YX-$LiNbO_3$ piezoelectric clystal. An aluminium was deposited on the clystal as the IDT and reflector. Operating frequency of the SAW device is 51.5MHz. In this paper, a force sensor (FSR402) is used to determine the strain. The force sensor is fixed on the cantilever, which is shown in **Fig. 2**. As the cantilever is distorted by weights, impedance of the force sensor is changed. As reflected SAW depends on impedance that is connected to the reflector, impedance change of the force sensor is detected by using the SAW device. From calibration curve between force and impedance, the force is obtained. Then, the strain is estimated from the force.

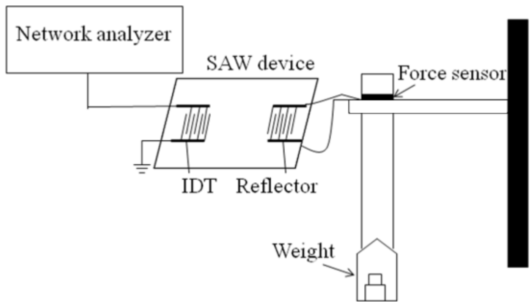

Fig. 2 Measurement system with SAW device and force sensor

4 Measurement results

Peak value of S11 in time domain was measured by using the network analyzer (see **Fig. 3**). Fig. 3 also shows simulated result, by using coupled mode theory. Both results agree well. When the cantilever was distorted by weights, S11 was changed because of impedance change of the force sensor. The relation between S11 and weight is plotted in **Fig. 4**. The figure indicates that the weight is uniquely determined from the S11. Goal of our research is to detect the strain. Fundamental characteristic of the force sensor at 51.5MHz was measured by using an impedance analyzer. The result is shown in **Fig. 5**.

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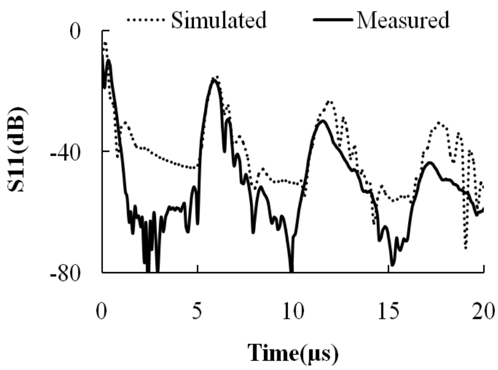

Fig. 3　Time response

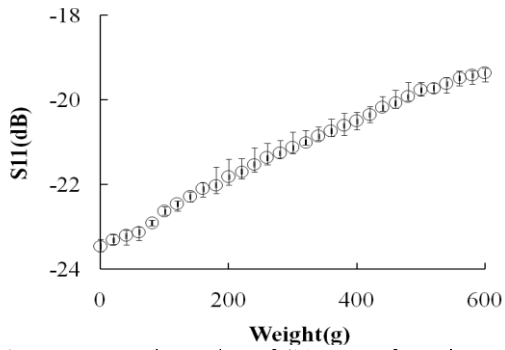

Fig. 4　Measured results of S11 as a function of weight.

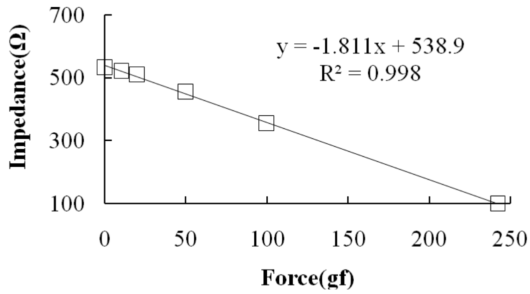

Fig. 5　The relation between force and impedance

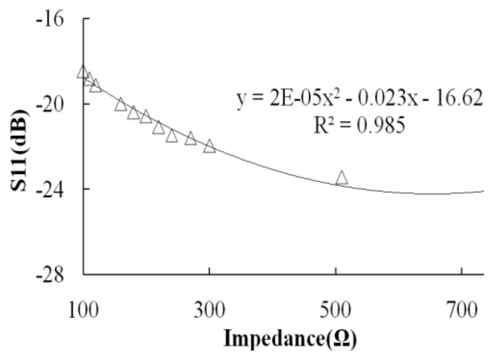

Fig. 6　The relation between impedance and S11

To use the calibration curve, we need the relation between S11 and impedance. In **Fig. 6**, measured results of S11 as a function of impedance is plotted. From Figs. 4, 5 and 6, the force applied to the force sensor is determined.

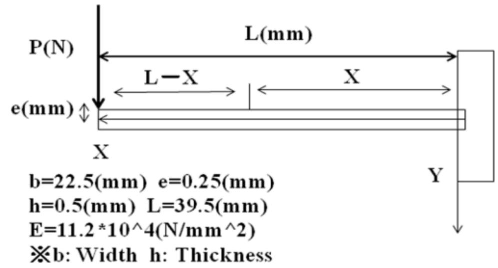

Fig. 7　Parameters of the cantilever

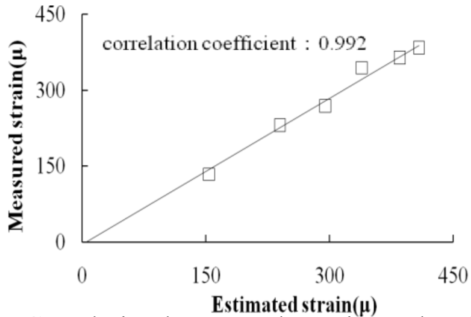

Fig. 8　Correlation between the estimated and measured strain

5. Estimation of the strain

By using the force obtained and eq. (1), the strain, ε, is estimated.

$$\varepsilon = \frac{-P(L-X)}{E} \cdot \frac{12}{bh^3}(-e) \tag{1}$$

In this paper, in **Fig. 7**, we estimated the strain of X=20. The estimated strain and measured ones by using a strain gage are shown in **Fig. 8**. From Fig. 8, it is found that there is a high correlation. Therefore, we concluded that we could estimate the strain by using the SAW device and force sensor.

6. Conclusion

In this paper, we discussed a measurement system in combination of a SAW device and a force sensor for detecting the strain of the cantilever. It was found reflection characteristic of the reflector depends on impedance that is connected to the reflector. We estimated the strain by estimating S11 without power supply and electric circuit at sensors. If the SAW device is used as a wireless sensor, combination of the SAW device and force sensor will be used for health monitoring of structures.

References

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