WIRELESS SENSOR USING SURFACE ACOUSTIC WAVE

T. Nomura[+], **A. Saitoh**[+], **and H. Tokuyama**[*]

+Faculty of Engineering, Shibaura Institute of Technology, Tokyo, Japan
[*] Moritex Coporation, Yokohama, Japan
nomurat@sic.shibaura-it.ac.jp

Abstract

A new wireless sensor has been fabricated by using SH-SAW device. Shear horizontal mode surface acoustic wave (SH-SAW) has a unique characteristic of complete reflection at the free edges of the substrate. The phenomenon makes it possible to design the reflecting delay line. In this paper, the SH-SAW are excited on a 36°YX $LiTaO_3$ and the right angle edge of the substrate has been used to reflect these waves. A wireless electronic system for remote sensing was fabricated by using the reflecting SH-SAW delay line. The reflecting SAW delay line was used as a sensor element and operates in a passive mode. Both the phase and amplitude of the SH-SAW reflected from the edge were measured as a response of the sensor. Experimental results on the measurement of liquids and vapor showed that the passive SH-SAW sensor system is very suitable for wireless sensing.

Introduction

The sensor technology rapidly develops today. The sensor using the surface acoustic wave (SAW) device also begins widely to use in various fields such as monitoring of the environment, process control of the chemical reaction plant, analysis in the medical and bio-sensing. [1] SAW devices are well known as electronic devices and have many unique features.

By using these SAW device technologies, it is possible to make various type sensors. For example, because several SAW devices can be constitute on one chip, it is possible to integrate some sensors in one plane. It can be miniaturized by using high frequency. In recently, SAW sensor for wireless identifications system have been also made. [2,3]

It is known that a specific cut surface of some piezoelectric materials also propagates the surface wave in the shear horizontal (SH) mode [4]. An SH-mode SAW contains a single particle displacement component, which is horizontal to the surface and perpendicular to the direction of propagation.

SH-SAW, which propagates on the surface of a piezoelectric substrate, produces complete reflection, if a right-angled incidence is made on a perpendicular edge. The phenomena have several advantages in the design of the electronic devices and sensors. [5,6]

In this paper the reflecting delay line sensor using complete reflection phenomenon of SH-SAW at the edge of substrate is investigated. [7] Both the phase and amplitude of reflected wave were measured as a sensor response. The electronic circuit is also proposed to accurate measurement of the phase. Finally, the wireless remote sensing system and its application on measurement of liquid and vapour sensing is shown.

Remote sensor system

Sensor structure

A schematic view of passive SAW sensor is shown in Fig.1. The sensor is composed of an interdigital transducer (IDT) for exciting and receiving the SAW, arranged on a piezoelectric substrate at an appropriate distance from and in parallel with the substrate edge.

The propagation characteristics of SH-SAWs depend on the surface conditions, particularly on whether the propagation surface of the SAW is shorted or not. Especially if the surface is electrical open, a surface skimming bulk wave (SSBW) is generated and the sensor operations are interfered. Therefore, in this study the surface was shorted periodically using metallic strips instead of completely shorting the surface. Figure 1 also shows the three channel passive SAW sensor having difference propagation length and the surface of each channel have short, open, and grating propagation paths, respectively. In the grating channel, metal strips (Al) with one eighth of a wavelength wide were arranged on the path.

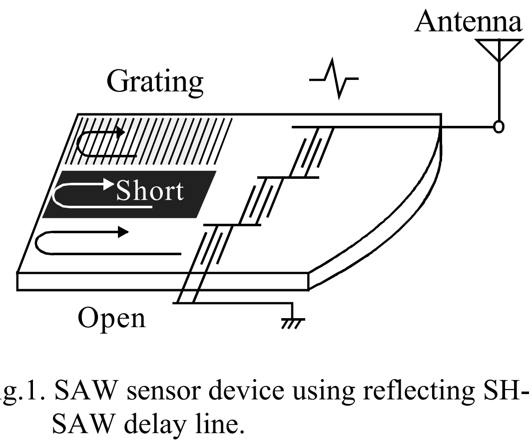


Fig.1. SAW sensor device using reflecting SH-SAW delay line.

The feature of the sensor is that a twice propagation distance can be obtained to improve the sensitivity, and if tone burst or impulses are input, the responses are obtained at a deference delay times according to the propagation distance.

Working Principle

An electro-magnetic wave radiated from the transmitting system (Fig.2) is received by the antenna of passive SAW sensor showed in Fig.1. The IDT which is connected to the antenna transforms the received signal into a SAW. The SAW propagates on the surface and is reflected by the edge of the substrate.

The reflected SAW is reconverted into an electrical signal by the IDT and re-transmitted to the receiving unit. This RF response contain a lot of information about the propagation and reflection properties of the SAW. The receiving unit (Fig.2) evaluates the amplitude, phase, and time delay of the RF tone burst.

Remote sensing system

Figure 2 shows the schematic diagram of a wireless sensor system using the reflecting SAW delay line [5, 6]. The system consists of passive reflecting SAW sensor (sketched in Fig.1) and high-frequency electronic system for the transmitting and receiving signal.

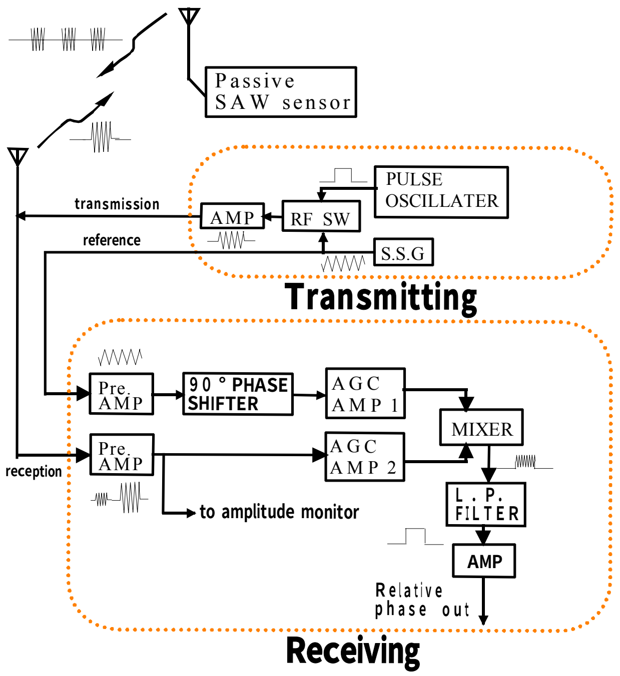


Fig.2. Schematic diagram of wireless remote SAW sensing system.

In this remote sensor system, it is necessary to separate the output signal from the input signal. Moreover, the phase and amplitude of the reflection SH-SAW contain a lot of information about the environment of the sensor device. Therefore, in order to obtain the responses at separate times and to measure the phase precisely, a tone burst is used in the system. The tone burst signal generated by the pulse oscillator and RF oscillator, is feed to the transmitting antenna. The received tone burst on the SH-SAW delay line is reflected at the free edge and detected by the same IDT connected the receiving antenna.

The phase change of the outputs is detected by feeding the outputs to a double-balanced mixer (DBM). Specifically, the phase of reference channel is delayed by the phase shifter 90º to improve the linearity of the DBM output characteristics. Moreover, the levels of the two signals are then uniformed via the automatic gain-control (AGC) amplifiers before being input to the DBM. By using these circuits, the accurate measurement of slight phase changes is possible. In the system, the output of the phase detector changes linearly to the phase difference by up to ±50º.

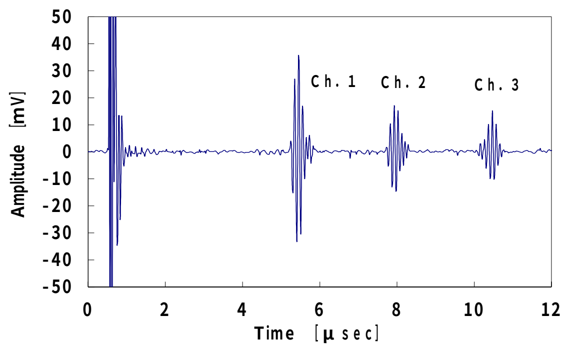


Fig.3. Typical output waveform obtained by the reflection wave at the edge of the substrate.

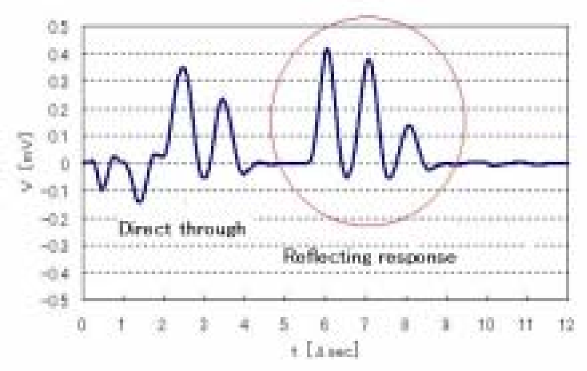


Fig.4. Waveform the phase difference obtained reflection response.

Figure 3 shows the typical RF waveform of output and Figure 4 shows the phase change of the output signal obtained by the reflection system. These experiments have be done by using the reflecting SH-SAW delay line fabricated on 36º YX $LiTaO_3$ substrate having 40 MHz of center frequency. The distances from the edge to IDT are 150λ, 200λ, 300λ (λ: wavelength). In this experiment, the continuous wave from RF oscillator was used as the reference signal, and the phase change by velocity difference of two channels was estimated as the voltage of the DBM. The output signal is observed at the position which is not affected by the environmental ethos.

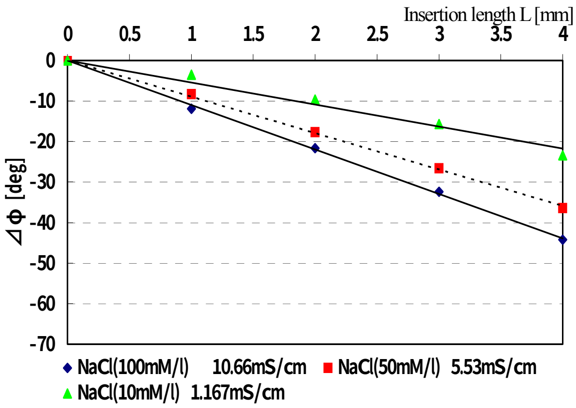
Experimental

In order to verify the performance of the SH-SAW sensor system, the experiment was conducted using the system shown in Fig.1 and Fig.2.

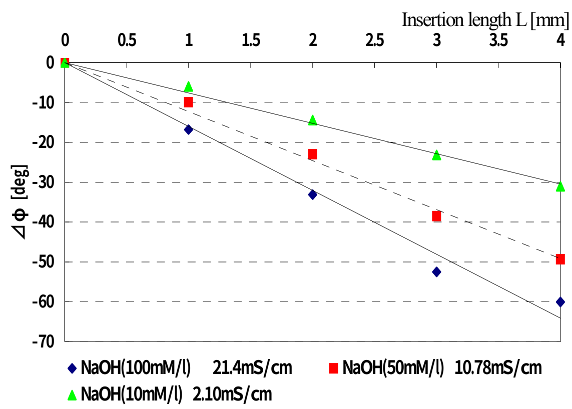
Liquid Sensing

The reflecting delay line was inserted with the perpendicular into the sample liquid from the edge. The output of the reflected wave was measured as a function of the insertion length.

Figure 5 shows the results when a conductive liquid, NaCl and NaOH solution, was used as a sample liquid. Each curve of figure (a) and (b) shows the phase changes for concentration of 10, 50, and 100mM/l of the mixture, respectively.



(a) Sodium chloride (NaCl).



(b) Sodium hydroxide (NaOH).

Fig.5. The relationship between phase difference and insertion length L.

The difference in gradient of these curves depends on the electrical effect of the sample liquids, which shows a conductivity of the mixture.

The above results suggest that the remote sensing system utilizing reflecting SAW sensor is very promising.

Vapor Sensing

In order to verify the sensitivity of the sensor as gas sensor, fundamental experiments were conducted for sensing the humidity. The propagation path was coated with a hygroscopic polymer film deposited by Langmuir-Blodgett(LB) transfer technique. The phosphatidylethanolamine was used as a hygroscopic material.

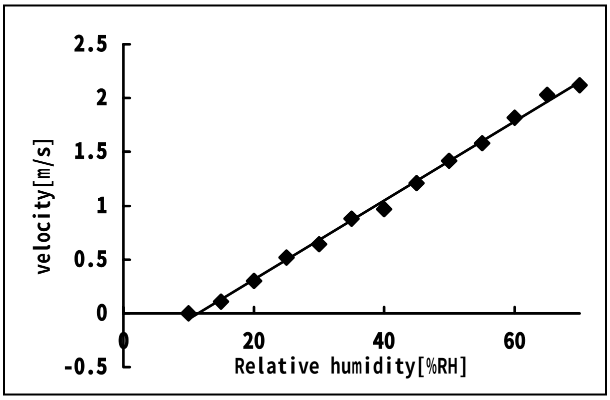


Fig.6. Variation of SAW velocity as a function of relative humidity (%RH).

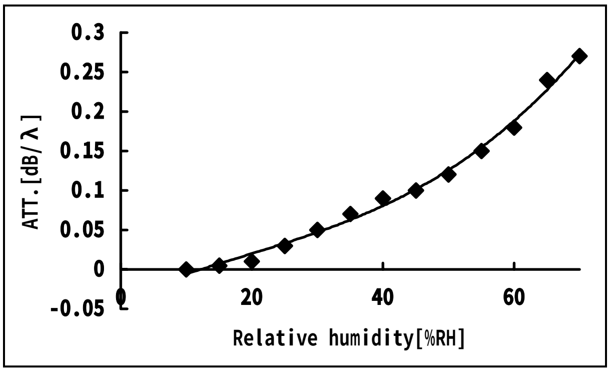


Fig.7. Variation of SAW attenuation as a function of relative humidity (%RH).

The variation of the SAW velocity and attenuation corresponding to the humidity are shown in Fig.6 and 7. It is found that the variation of the film due to humidity causes linear changes in the SAW velocity.

Between 10 and 70% in RH, the SAW velocity varies almost linearly with humidity, with a slope of 0.33 m/s per 10% change in RH. The attenuation due to the absorption of moisture remains less than 0.3dB/λ. The insertion loss was caused by the dielectric loss.

The above results suggest that a SAW humidity sensor utilizing LB film is promising.

Conclusions

A wireless remote sensing system has been demonstrated. Reflecting SAW delay line was fabricated on a 36° YX $LiTaO_3$ crystal. The right edge of the substrate was used to reflect the SH-SAW and a one-port SAW delay line was constructed. The wireless remote sensing system was constructed by using the delay line. Experimental results showed that the system is very suitable for remote sensing of the environments.

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