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Study on the Biosensor Using Surface Acoustic Wave sensor

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1. Introduction

Biosensors are included in sensors, which are used when studying enzyme, bacteria, and tissues of the body [1,2]. They are also used in measurement system sensors, which measure the mechanism of living systems. They are used in various fields such as medical, food, and environmental industries because of their merits to measure the objects directly without separating them as well as their peculiarity, convenience, and microanalysis to react only to the designated objects [1,3-5]. But most of the biosensors developed until now have only a single function, so it is difficult to get complex information from a living body. Therefore, it is necessary to develop an advanced sensor to measure at the molecular level and to correctly judge general information of a living body. In this research, we have tried to develop a kind of advanced biosensor mentioned above using surface acoustic wave (SAW).

Surface acoustic wave (SAW) devices are widely used as electronic filters, delay lines, resonators in today's communication systems. Furthermore, SAW devices for wireless identification systems, the so-called inter-digital transducer, have been in practical use for over ten years. Also, SAW devices have been applied as chemical and physical sensors for gas and liquid phases. The main function of the SH-SAW sensor is to detect liquid properties with high sensitivity. In particular, the sensitivity for the detection of liquid electrical properties is the highest among the various sensors, because the piezoelectric substrate of the SAW sensor has a large electromechanical coupling coefficient. In the fields such as medicine and environment, the development of the small SAW sensor can measure the characteristics of the liquid. For use as physical, chemical or biological sensors, SAW components are modified for increased sensitivity to the respective measurements. Therefore, there are merits to make a biosensor smaller, to measure in real time, and to make use of only small amount of the test material [6]. To oscillation this SAW, we are using a single crystal such as $LiNbO_3$ (LN), $LiTaO_3$ (LT), ZnO, GaAs, Quartz and etc., because these materials have stability about temperature and surface is good smooth. The frequency band and sensitive of these materials are rather low because of a low electromechanical coupling coefficient [7,8]. If we use PMN-PT:$Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$, we can make a device that has a high frequency band and sensitive and that generates large sound pressure because of high electromechanical coupling coefficient.

In this research, in using a piezoelectric material of PMN-PT, which has a high electromechanical coupling coefficient, we have tried to see if the material can be practically available as a new SAW biosensor to detect protein.

2. Experiment

The piezoelectric material of PMN-PT, which we used in this research, has been crystallized by Bridgman method by the help of iBULe Photonics Ltd. The grown crystal was cut into a size fit to produce sensors, and wafers were made. We used a photolithography method to make IDT on the 5" PMN-PT wafer. To evaluate the capability of the manufactured sensors, we applied an oscillation circuit method. Three types of sensors were experimented with and the characteristics of each of them are shown on Table 1. We used a LT piezoelectric substrate in type 1 and 2 and a PMN-PT piezoelectric substrate in type 3.

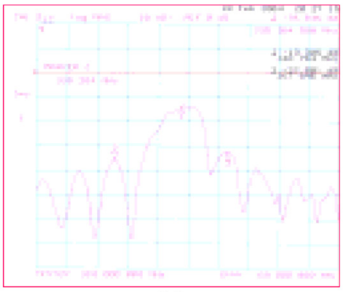
Table I Type of SAW sensors

Font size	Cutting degree and Piezo-electric material	Wave length(㎛)
Type 1	36° X-Y cut $LiTaO_3$	12
Type 2	36° X-Y cut $LiTaO_3$	16
Type 3	PMN-PT	40

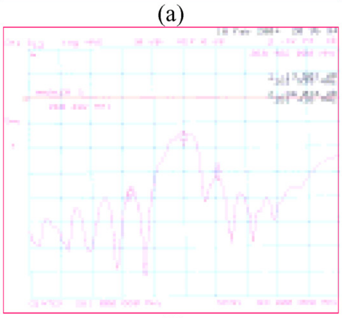
3. Results and Discussions

Fig. 1 shows the results of the frequency response characteristics of the SAW with the LT piezoelectric substrate (type 1 and 2). The center frequency of type 1 was measured as 348.764 MHz and type 2 was 261.939 MHz. Seen above in the figures, when comparing the response characteristics of the center frequency with the surrounding frequency, we don't have satisfactory results from these sensors, as the filtering effects of them were not good except in the center frequency.

Fig. 2 shows the results of the frequency response characteristics of the SAW sensor with the PMN-PT piezoelectric substrate (type 3). We've got the resulting figure by using wave length 40 ㎛ and velocity 2,336 m/sec. With this experiment, we got a center frequency of 59.3 MHz. Comparing the amplitude of the surrounding frequencies to the central frequency in the figure, the filtering effects of the surrounding frequencies around the central frequency gave better results than type 1 and 2. According to the information provided by iBULe Photonics Ltd., the electromechanical coupling factor of PMN-PT substrate is better than others substrates. PMN-PT substrate is 0.933, LN substrate 0.02, and PZT substrate 0.7 (F/m).



(a)



(b)

Fig. 1 Frequency response in $LiTaO_3$ (NT) sensor without absorber at input and output probe. (a) Type 1, (b) Type 2

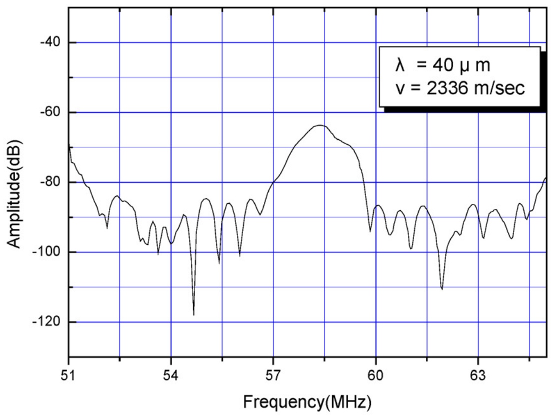


Fig. 2 Frequency response of SAW sensor fabricated by PMN-PT piezoelectric substrate (Type 3).

4. Conclusions

Seen above, in this research, the frequency filtering of the central frequency of the PMN-PT substrate is a superior result to that of the LT substrate, but the result was not completely satisfactory. We know there is a problem in the design of IDT pattern. The waves transferred through the input terminal forms SAW which is sure to be transferred to the direction of the output terminal and the backward direction of the input terminal. This reflected wave is reiterated with SAW, which is transferred to the output direction, and so the frequency filtering gives a not good result. The electro-mechanical coupling factor of the PMN-PT substrate is excellent, and as such we can use it as a SAW sensor, in the near future, provided that there will be a new IDT design to increase the frequency filtering. With the results we've gotten, we are planning to design a new IDT pattern to increase the frequency filtering effects of PMN-PT substrate of the central frequency. We hope to measure various physiological active factors with this newly developed substrate. At this time, the wave transferred to the rear direction is to be reflected by the input terminal and produces a reflected wave, which is transferred to the output terminal.

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