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SAW Gas Sensor with Self-Temperature-Compensation Characteristics at 1st- and 3rd-Harmonic Frequencies, and Investigation of Its Loss-Reduction Technique for Sensor Network

センサネットワーク用弾性表面波ガスセンサの自己温度補償及び低消費電力化の研究

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1. Introduction

Sensor network is treated as a new service which will have a big impact on our lives and grow to a giant industry like the cellular-phone system. We have been studying the sensor network to monitor hydrogen gas leakage from future fuel-cell cars. In this paper, we proposed a new SAW gas sensor which can be installed within ZigBee's sensor nodes. The sensor consists of three SAW delay lines formed on a single piezoelectric crystal. Moreover, the fundamental and 3rd-harmonic frequency signals generated by division and multiplication of ZigBee's 2.4Hz signal are used in our sensor. By changing the fundamental and 3rd-harmonic frequencies, wide dynamic-range can be achieved compared with conventional SAW sensor.

2. Basic sensor configuration

The three delay lines have different delay lengths to one another as shown in **Fig.1**. A sensor delay line, D-1, D-2 and D-3, have L, $L-\lambda_0/8$ and $L+\lambda_0/8$ respectively, where λ_0 is wavelength of fundamental frequency SAW. D-2 and D-3 which provide the standard phases are isolated from measuring gas. The fundamental/3rd-harmonic waves are used to detect sensing gas. SAW energy concentration is about a wavelength toward depth in a substrate. Therefore, the 3rd-harmonic wave is more sensitive than the fundamental wave against change of the surface propagation condition. For example, in the case of low gas density, 3rd-harmonic wave is used, while in the other case fundamental wave is used. By this method, the dynamic-range is extremely extended and the measurement accuracy is improved.

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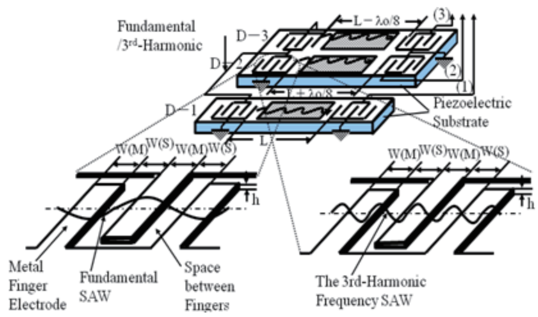

Fig. 1 New SAW gas sensor for sensor network

3. Experiment

To verify our proposal, we carried out basic experiment using **Fig.2**'s structure, which is equivalent to that shown in **Fig.1**. **Fig.1**'s D-1, D-2, and D-3 were equivalently achieved by the three same delay lines with added external different electric-transmission lines as shown in **Fig.2**. The phases of the transmission lines, $\theta_i (i = 1, 2 \text{ and } 3)$, are as follows: θ_1 and θ_2 are arbitrary, and $\theta_3 = \theta_2 + \pi/2$. In the experiment, as θ_i's depend on the transmission-line lengths, we determined them as $\theta_1 = -130^\circ$, $\theta_2 = -300^\circ$ and $\theta_3 = -210^\circ$ at the fundamental frequency at room temperature. We used a 128° Y-X $LiNbO_3$ as a substrate. Measured temperature characteristics of phases of **Fig.2**'s (1), (2) and (3) at the fundamental frequency (75MHz) are shown in **Fig.3** (a). Phases of (1), (2) and (3) are about $230^\circ, 60^\circ$ and 150° respectively at room temperature, and the phase shift due to temperature changes are almost same for all outputs. Phase difference between (2) and (3) is 90°. Thus, projecting (1) onto the axes for direction (2) and (3) can provide correct phase shift only due to the sensing-gas effect over wide-temperature range. Experimental results at the 3rd-harmonic frequency (225MHz) are shown in **Fig.3** (b). Almost same characteristics were achieved. Phase difference between (2) and (3) in also 90°, which shows the same procedures as those at the fundamental frequency can be applied. These results indicate a possibility to achieve wide-dynamics range from coarse sensing to fine sensing by switching the fundamental and 3rd-harmonic frequencies.

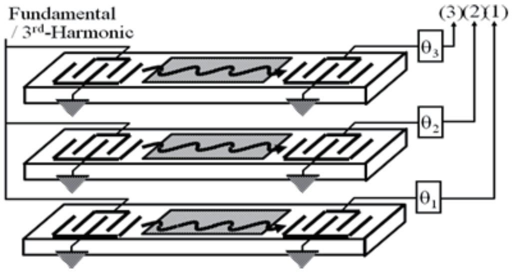

Fig. 2 Experimental sensor equivalent to Fig.1

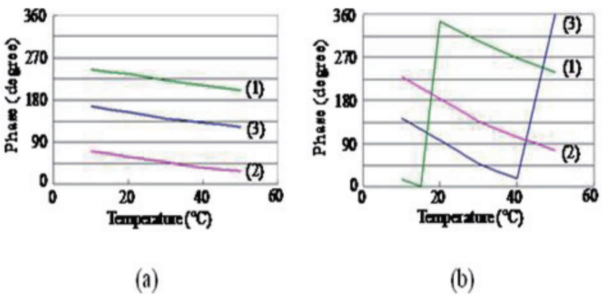

Fig. 3 Experimental temperature characteristics for three output phases: (a) Fundamental frequency; (b) 3rd-hamonic frequency.

4. Investigation of loss reduction

Insertion losses of the delay lines used in **Fig.2**'s experiment were 25 to 30dB, which shows that it might be difficult to adopt this sensor to sensor nodes. Because the sensor node requires extreme low-loss operation. We have invented new low-loss resonator-type sensor delay lines shown in **Fig.4** (a). Z_i's are shown in **Fig.4** (b). Z_1 and Z_2 are connected in a lattice circuit, which is used as a sensor. Pairs of Z_1's and Z_2'2 and Z_1"and Z_2" are also connected in lattice circuits, which provide standard phases with $\pi/2$ phase difference same as the previous one.

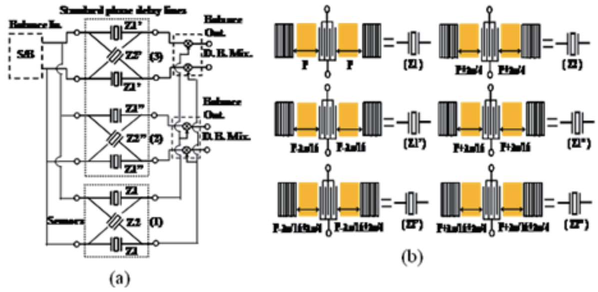

Fig. 4 New resonator-type low-loss sensor: (a) Delay lines with lattice circuit; (b) SAW resonators

5. Conclusion

We showed a novel SAW gas sensor had self-temperature-compensation characteristics and wide-dynamic ranges. We also investigated loss-reduction techniques for sensor delay lines. We will continue to design and experiment with the new invented delay lines.

Reference

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