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Magnetic Sensor based on SAW Resonators
弾性表面波を用いた磁気センサ

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1. Introduction

Surface acoustic wave (SAW) based sensors have been presented by many researchers and lots of kinds of sensors such as biosensors have been reported. To the best of our knowledge, however, there has been no report of magnetic sensors based on SAW resonators. On the other hand, a wireless passive SAW sensor based on SAW resonators have been reported and pressure, torque and temperature sensors have been proposed using the method of detecting a reflection signal from a SAW resonator against an interrogating signal [1, 2, 3]. Therefore a high-Q resonator is required theoretically.

In this paper, our new-type magnetic SAW sensor which consists of only inter digital transducers (IDTs) and quartz substrates has been realized. This sensor is able to be used as a element of the wireless passive SAW sensor.

2. Sensor Design

The structure of our magnetic sensor is very simple and equals to that of usual one-port SAW resonators. Only IDTs made of Ni, a general magnetostrictive material, are fabricated on quartz substrates. A strain of the IDTs occurred by applied magnetic field makes the resonant frequency of the sensor shift due to changing the elasticity coefficients of the IDTs and the stress boundary conditions on the surface of the substrate.

On the other hand, the authors have reported the existence of a leaky surface acoustic wave (LSAW) having only a shear horizontal (SH) component which has a large electromechanical coupling factor, a large reflection coefficient and excellent temperature stability on the ST-cut 90°X propagation (direction perpendicular to the X-axis) quartz fabricated IDTs made of high-density metals on its surface [4]. As it is suitable for this sensor because Ni has a high density, the ST-90°X quartz is used as a substrate in this experiment. The resonant frequency has been designed about 315MHz for following measurement. The film thickness of the IDTs is 0.02 λ (λ=14.6 um) and their finger pairs are 40. The reflectors are 50 fingers.

3. Magnetic Characteristics

Figure 1 shows the dependence of the resonant frequency shifts (Δf) on applied magnetic fields each directions. The X-axis and the Y-axis magnetic fields are parallel and perpendicular to the SAW propagation, respectively. It is found that this sensor has dependence of magnetic characteristics on the direction of magnetic fields.

The dependence of the Q-factors of the SAW resonator on applied magnetic fields is shown in **Fig. 2.** It is interesting that the Q-factor gets to be improved as the strength of the Y-axis magnetic field increases, while a drop point of them exists when the X-axis magnetic field is applied.

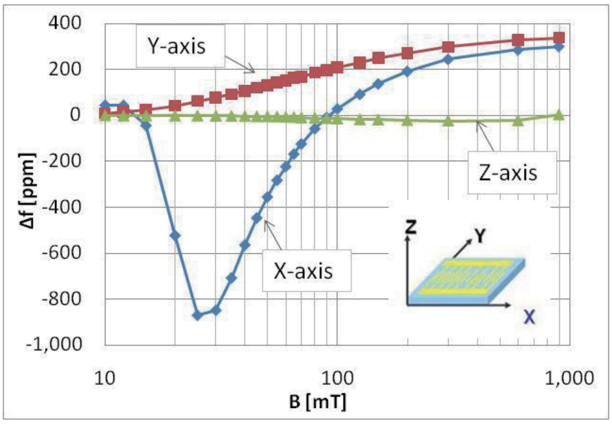

Figure 1. Dependence of the resonant frequency shifts (Δf) on applied magnetic fields along X, Y and Z axes defined in the insertion figure, respectively.

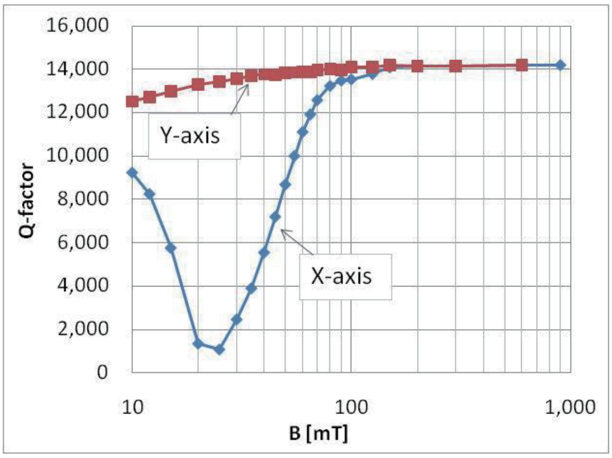

Figure 2. Dependence of the Q-factors of the SAW sensor on applied magnetic fields along the X-axis and the Y-axis, respectively.

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Figure 3 shows the dependence of the magnetic sensitivity on the metallization ratio of the IDTs under an applied magnetic field along the Y-axis. The shifts get to increase as the metallization ratio becomes large. The sensitivity range from 10mT to 1000mT is obtained at the metallization ratio of 0.8.

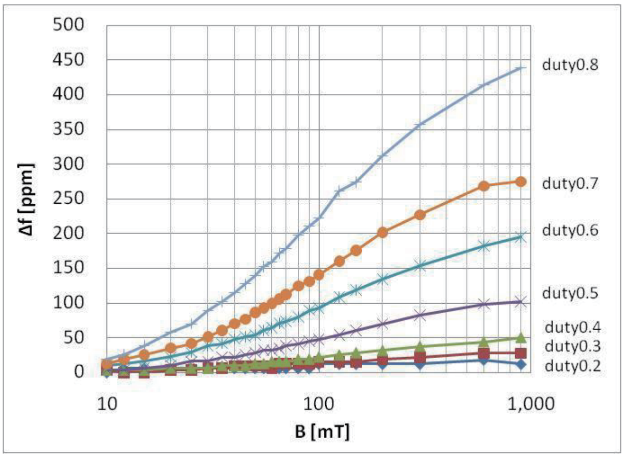

Figure 3. Dependence of Δf on applied magnetic field along the Y-axis and the metallization ratio of IDTs.

4. Wireless Sensing of a Magnetic Field

The authors have tried to apply this magnetic SAW sensor to a wireless passive SAW sensor using the conventional method reported in [1]. **Figure 4** shows the schematic of our wireless passive SAW sensor system. The magnetic SAW sensor is connected to a λ/2 dipole antenna directly. The explanation of an interrogation unit is omitted. In the measurement a neodymium-magnet having dimension ϕ 5mm x 2mm^t was approached to the sensor along the Y-axis in a ordinary room.

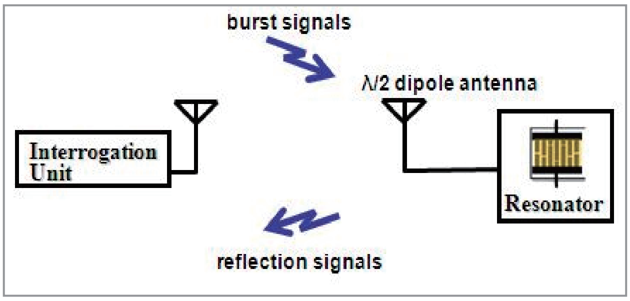

Figure 4. Schematic of the wireless passive SAW sensor system

Figure 5 shows the result of the measurement. The Y-axis in Fig. 5 indicates the center frequencies of the reflection signals from the sensor which are down-converted and counted in the interrogation system. It is found that the approaching of the magnet can be detected though the distance between two antennas is as short as 70cm because this measurement was accordance with the Japanese extremely low power radio station (the output power of - 42dBm).

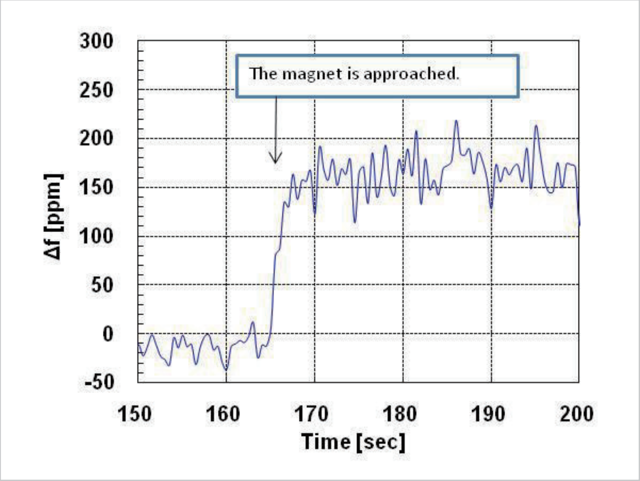

Figure 5. The measurement result of the wireless magnetic SAW sensor.

5. Conclusion

The authors have succeeded to develop SAW-resonators with a magnetic-sensitivity using IDTs made of Ni that is a magnetostrictive material, and found that this sensor has large dependence of the magnetic characteristics on directions of applied magnetic fields and the metallization ratio of the IDTs. The sensitivity range is from 10mT to 1000mT. In addition, the wireless magnetic sensor based on SAW resonators without any batteries has been proposed.

References

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