Magnetic Sensor based on SAW Delay Line using Galfenol Film

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Introduction
This paper presents a magnetic sensor based on a surface acoustic wave (SAW) delay line using galfenol film. Galfenol is a magnetostrictive material. As the surface acoustic wave travels, its velocity through the galfenol thin film changes depending on the external magnetic field. This is due to the delta E effect in which the elastic properties of a magnetostrictive material depend on its magnetization. In our SAW delay line, a relatively large velocity change, 0.9%, is obtained using the galfenol film compared to a -0.27% change in the TbFe₂ film – LiNbO₃ substrate configuration [1] and -0.02~0.07% change in the Ni film – LiNbO₃ substrate configuration [2].

Device fabrication
A pair of interdigital transducers (IDTs) for generating and detecting the SAW is fabricated on a piezoelectric substrate (quartz), as shown in Fig.1. The IDTs are designed for 50 ohm impedance and an operation frequency of 160 MHz. A 230 nm galfenol thin film is sputtered on the same substrate and lies in the path of acoustic wave. The film is sputtered at 300 watts for 30 minutes under 6.1 mTorr using a FeGa (18.4% Ga) target. Galfenol is chosen because it has a large magnetostrictive and delta E effect, and can be easily deposited by sputtering.

The resulting film shows a preferred orientation of (110) as indicated from the X-ray diffraction (XRD) measurement shown in Fig. 2. This is not surprising since (110) planes are closed-packed planes for BCC materials. With the (110) texture, the galfenol film grown on quartz has a great magnetostrictive effect in the film level [3].

Experiments and results
Experiments were conducted to measure the change in velocity as a function of an applied magnetic field, swept from 0.38T to -0.38T in the x-direction (see Fig. 1). The acoustic velocity change, \( \Delta V / V \), is determined by the group delay of received signals. As shown in Fig. 3, the maximum velocity change is around 0.9%. The trend of the velocity change switches at \( \pm 0.19 \text{kGauss} \) which corresponds to the coercivity of the galfenol film, as measured with a BH looper.

Fig. 4 shows the relationship between change in velocity and the direction of an applied constant field, 0.06 T in magnitude. The field starts along y-direction, rotates into x-direction and then back. The maximum velocity change reaches 0.9%. The results shown in Fig. 3 and Fig. 4 are from the same device.
A large velocity change \( \Delta V / V \) up to 0.9% is obtained in the magnetic sensor based on SAW delay line using Galfenol thin film. This change is several times as large as that previously reported on Ni or TbFe₂ film – LiNbO₃ substrate configuration device. Therefore this delay line is much better for practical application.
References

Fig. 1. The basic configuration of a SAW line.

Fig. 2. XRD measurement of galfenol film. The peak centred at 43 degree is indicative of preferential (110) texture.

Fig. 3. Dependence of $\Delta V/V$ on applied field.

Fig. 4. Dependence of $\Delta V/V$ on the angle of...