SAW MAGNETIC FIELD SENSOR USING MAGNETOELASTIC MULTILAYERED THIN FILM

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Background, Motivation and Objective

Recent progress in the elaboration of new magneto-elastic materials such as multilayered piezomagnetic composites make them widely used in the development of sensors, actuators... More specifically, the combination of SAW and magnetostrictive material leads to the development of innovative magnetic field sensors that could be integrated in harsh environment. In such sensors, the velocity of the SAW follows the magnetoelastically-induced changes of the shear modulus according to the bias magnetic field through the ΔE-effect.

The objective of this work is the development of a highly sensitive surface acoustic wave based magnetic field sensor. An equivalent piezo-magnetic model developed in a previous work [1,2] was successfully used to model the magneto-elastic coupling occurring in such devices as reported in the following lines.

Statement of Contribution/Methods

In this work, we report a SAW delay line magnetic field sensor that uses pure shear-horizontal acoustic waves manufactured on ST-90ºX quartz cut using a RF sputtered uniaxial multilayered 14 x [$TbCo_{2(3.7nm)}$/$FeCo_{(4nm)}$] nanostructured thin film as sensitive layer, The propagation direction of the wave is orthogonal to the X-axis of the ST-cut quartz wafer which is also the easy axis (EA) of the magnetic thin film. In order to assess the magnetoelastic coupling effect on the SAW velocity, the magnetic sensor is biased with a varying magnetic field (direction and amplitude), and measurements were performed on S_{21} parameter with a vector network analyzer (Agilent 8753ES).

Results/Discussion

The manufactured SAW delay line after thin film deposition is shown in Figure 1. Figure 2 (top) shows the vectorial magnetization of the multilayered magnetic thin film when biased with a varying magnetic field along its hard axis. The normalized phase and amplitude of the insertion loss are depicted in Figure 3 (bottom) for the third harmonic at 1.2 GHz (15 dB and 250º phase shift for 100 Oe variation). As highlighted in Figure 2, the hysteretic nature of the multilayered magnetic thin film is reflected in the S_{21} amplitude. As depicted in Figure 3, the phase shift induced on SAW propagation is then translated into a velocity shift. The velocity shift and its bias magnetic field dependent shape, obtained through experimental measurements (at 1.2 GHz), matched perfectly with the calculation based on an equivalent piezomagnetic model developed in a previous work.

The relative velocity shift obtained for the third harmonics is around 2.5%. It represents a maximum phase velocity shift close to 250% for a ratio close to 1 between magnetoelastic film thickness and wavelength which is quite noticeable.

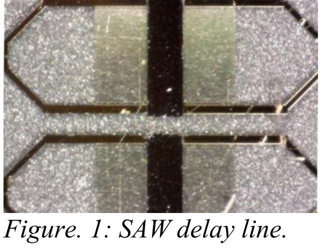

Figure. 1: SAW delay line.

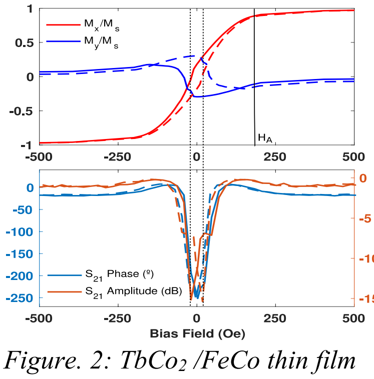

Figure. 2: $TbCo_2$ /FeCo thin film magnetization characteristics (top). Insertion Loss S_{21} (bottom)

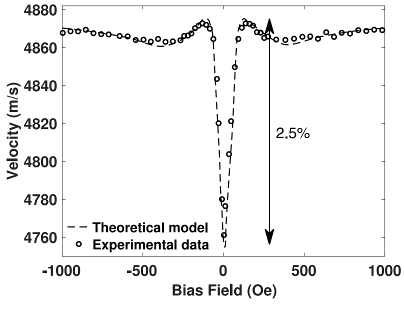

Figure. 3: Theoretical calculation (dash) and experimental results (circles) for SH wave's velocity.

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