Piezoelectric Surface Acoustic Wave (SAW) Device with Simulated Poling Condition

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Abstract

FEM (Finite Element Method) modelling software such as COMSOL Multiphysics® can be a powerful tool for modelling the behavior and response of piezoelectric materials and devices [1]. Devices based on piezoelectric crystals are particularly well suited, because the polarization magnitude in crystals is predetermined and its orientation is defined by how it was cut with respect to the lattice structure. In the case of polycrystalline piezoelectric ceramic materials, the overall polarization vector in the material is not oriented in one single direction nor is constant all over the material. Therefore, a poling process, where a strong electrical field is applied across the material to align the dipole domains in one particular direction on a macroscopic level, should be performed. In this paper SAW [2] piezoelectric ceramic devices have been investigated. A diagram of a generic SAW sensor is shown in Figure 1, physical SAW sensors can be used to measure temperature, humidity, pressure, force, etc. [3]. Chemical/biological SAW sensors can also be used to detect oxygen, pathogens, etc. [4,5]. The initial SAW device has a polarization perpendicular to the substrate as shown in Figure 2. This means that the piezoelectric transduction relies mostly on d31, the charge coefficient in the transverse direction. In the case of Lead Zirconate Titanate, the most common piezoelectric ceramic, d31 is often less than half of the value of d33, the charge coefficient in the thickness direction [1]. Therefore a second SAW device is suggested, one that would gain higher sensitivity by using the d33 instead of the d31 mode of operation. This can be achieved by applying a high electric potential to one of the interdigitated electrodes while grounding the corresponding electrode, a polarization such as the one shown in Figure 3 can be achieved. This would not only enable the use of the higher charge coefficient for operation, but also would simplify the fabrication process of the device.

The standard SAW device shown in Figure 2 and the interdigitated poled SAW device in Figure 3 have been modelled using the Piezoelectric Devices interface in COMSOL Multiphysics. In order to correctly model the interdigitated poled SAW device, the poling process has also been modelled by simulating the resulting electric field from the applied voltage on the electrodes and mapping the resulting magnitude according to the polarization magnitude correlated to the virgin hysteresis curve of the piezoelectric ceramic. The orientation of the polarization has been aligned in the direction of the simulated electric field. The module of the transfer function between the transmitting IDT (interdigitated transducer) and the receiving IDT provides the proper sensitivity comparison of the two SAW devices.

It has been shown that COMSOL can model not only piezoelectric devices but also the poling process in the case of piezoelectric ceramic materials, which is of utmost interest

for a piezoelectric ceramic producer such as Meggitt A/S. In this paper the focus has been mainly on SAW devices, but it can be applied to any piezoelectric ceramic based devices with non-trivial polarization.

Reference

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[4] M.-I. Rocha-Gaso et al., Surface Generated Acoustic Wave Biosensors for the detection of Pathogens: A Review, Sensors, Vol. 9, pp. 5740-5769 (2009)
[5] D. W. Greve et al., Surface Acoustic Wave Devices for Harsh Environment Wireless Sensing, Sensors, Vol. 13, pp. 6910-6935, 2013.

Figures used in the abstract

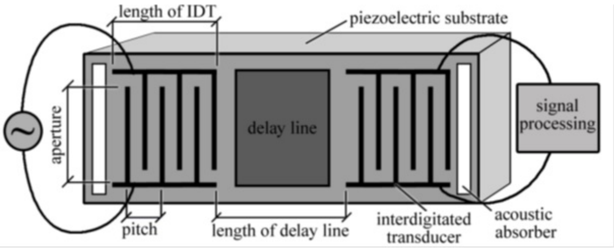

Figure 1: A generic SAW sensor [2].

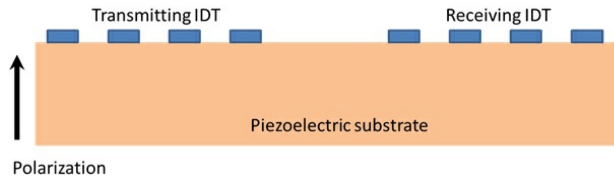

Figure 2: Cross-sectional view of a SAW device with constant polarization orientation.

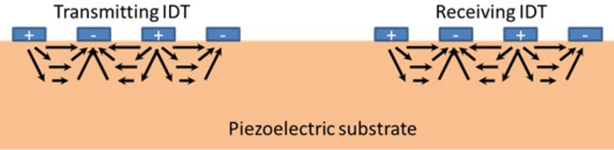

Figure 3: Cross-sectional view of a SAW device poled using the interdigitated electrodes.