Orientation of Piezoelectric Crystals and Acoustic Wave Propagation

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Abstract

Surface acoustic wave (SAW) devices are commonly used as wireless filters, resonators, and sensors. The confinement of acoustic energy near the surface of a piezoelectric substrate in a SAW sensor makes it highly sensitive for discerning surface perturbation. As sensors, SAW devices have the potential to provide a high-performance sensing platform with capabilities of remote and high-temperature operations. This is very attractive for SAW sensors because dangerous chemical and biological species can be detected in extreme conditions remotely. Since piezoelectric materials commonly used as SAW substrates are anisotropic, the performance of a SAW device depends on not only the cut angle of its substrate material but also the wave propagation direction. To produce high performance SAW devices, optimal orientations of the crystal cut for the piezoelectric substrate and the SAW propagation are crucial. This work takes advantage of COMSOL Multiphysics computational power to investigate this important problem. A two-port delay-line SAW device is used with two sets of interdigitated transducers placed atop a piezoelectric substrate and separated by a distance. For simplicity, the two ports of this SAW device are modeled as reciprocal and symmetric, i.e., S11=S22 (reflection coefficients) and S12=S21 (transmission coefficients). Several common piezoelectric materials (e.g., Langasite, Lithium Niobate) are examined under various different Euler angles. Insertion loss (-20log|S12|), resonant frequency (f0) and SAW travel velocity (v=λ*f0) are used as metrics for quantitative analysis. Here λ is the wavelength of the generated SAW. This work not only reveals how insertion loss and SAW travel velocity are affected by the crystal cut angles and the wave propagation direction but also demonstrates that computer simulation can provide a better and cost-effective way to identify an optimal crystal orientation for the development of high performance SAW devices.