Quartz Transducer Modeling for Development of BAW Resonators

L. B. M. Silva[1], E. J. P. Santos[1]

[1]Laboratory for Devices and Nanostructures, Electronics and Systems Department, Universidade Federal de Pernambuco, Recife, PE, Brasil

Abstract

Introduction: Piezoelectric transducers have its mechanism of detection based on mechanical wave propagation. For bulk acoustic wave (BAW) devices, changes in the solid structure by a physical quantity, such as: temperature, pressure, acceleration, and others, can be measured as an electrical signal, due to the piezoelectric effect. As the transducer operates in the shear thickness vibration mode the thickness of the structure determines the operating frequency of the resonator circuit. Quartz crystals in AT-cut are usually used as transducers because they have very good frequency stability [1]. In this paper, all the required steps to simulate the shear thickness vibration mode for the quartz in two and three dimensions are presented, the AT-cut is analyzed as example. The simulation was carried out with COMSOL Multiphysics 4.2a. Use of COMSOL Multiphysics: The piezoelectric coupling can be represented mathematically through the constitutive relations of piezoelectricity, where the elasticity, coupling and permittivity matrices can be selected for the AT-cut quartz [2]. The flowchart presented in the Figure 1 contained the step-by-step for simulations. Electrodes are assumed on both surfaces, and an external AC signal is applied. One electrode is set as the driving terminal and the voltage amplitude is 5 V, the other is set to ground. To simulate 2D, the type mapped mesh was generated with 100 x 25 finites elements. The mesh size is chosen to be at least ten times smaller than the fifth harmonic wavelength. For 3D analysis the structure is presented in Figure 2, the thickness direction must be along the y-axis for correct orientation of the AT-cut matrices. The type mapped mesh with 100 x 25 finites elements are defined as pattern in one surface parallel to the xy-plane and then a swept is done for 8 planes transverses to the z-axis, totaling 20,000 finites elements. Results: Studies are performed in the frequency domain and eigenfrequency modes. For a thickness of 200 microns it is expected a resonance at 8.3055 MHz for the first harmonic, the simulation showed resonances at 8.2852 and 8.2853 for 2D and 3D, respectively. For 3D simulation, the admittance and phase curves near the first harmonic are shown in Figure 3. The deformation can be seen in Figure 4. Conclusions: 2D and 3D BAW resonators are simulated for AT-cut quartz crystal. The resonances frequencies up to fifth harmonics were compared with theory and the errors are less than 1%. Further simulations are underway to use others orientations and thick electrodes, and to include loss factor damping in the BAW structures.

Reference

1. M. Weihnacht, “Links between temperature stable baw and saw crystal orientations,” in Ultrasonics Symposium IEEE, vol. 2. pp. 914–917 (2005).
2. J. Yang, Analysis of piezoelectric devices. World Scientific Pub Co Inc, 2006.

Figures used in the abstract

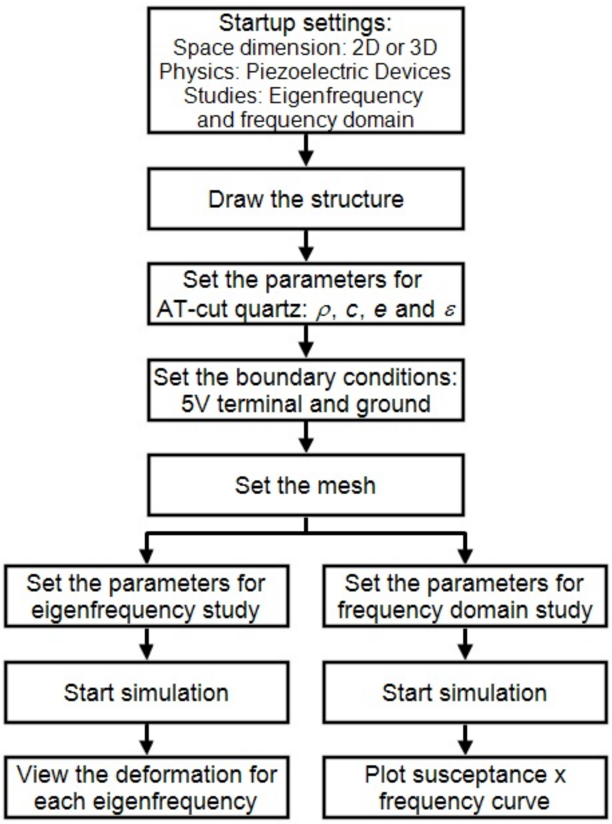

Figure 1: Flowchart for simulation of the AT-cut quartz.

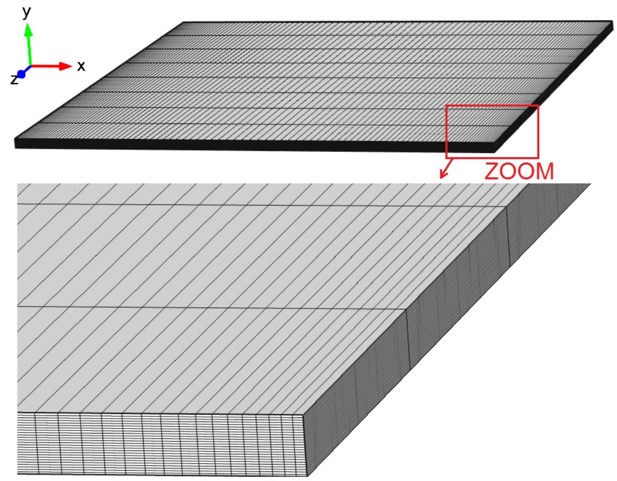

Figure 2: 3D quartz crystal plate resonator: 10115.28 x 10115.28 x 200 microns.

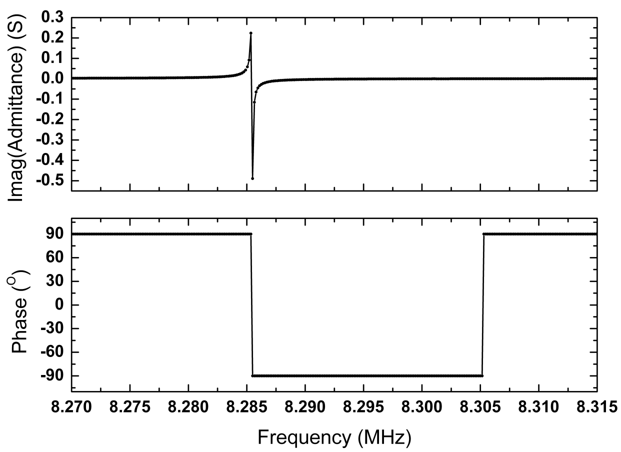

Figure 3: Admittance and phase for the first harmonic in 3D simulations. A step of 150 Hz is performed.

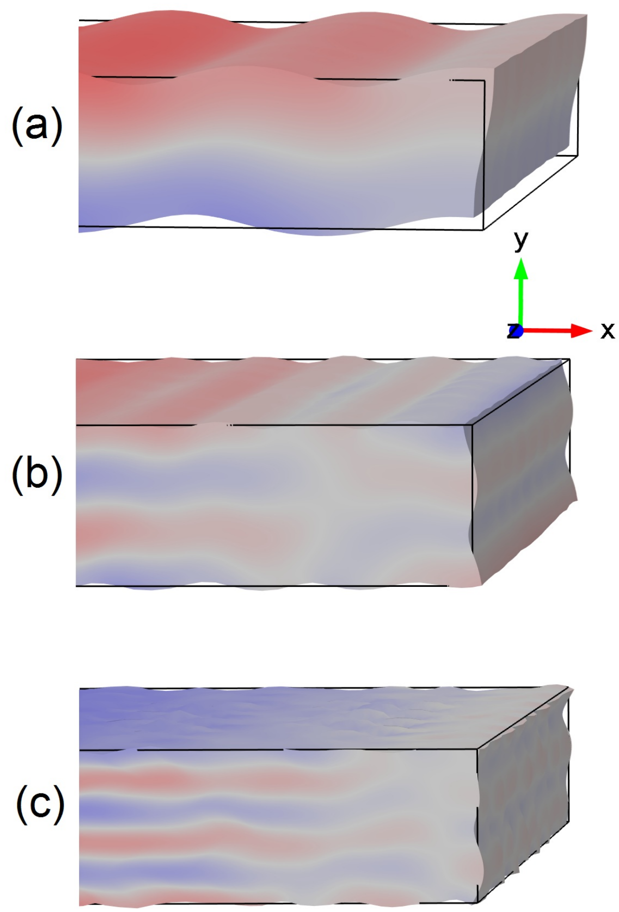

Figure 4: Deformations for the first (a), third (b) and fifth (c) harmonics.