Surface Acoustic Wave Properties (SAW) and Acoustic Streaming Characterization for Annular and Curved Electrodes on 128˚ Y-Cut, X-Propagating LiNbO3

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Abstract

Microfluidic devices and lab-on-a-chip (LOC) formats are attractive technologies for a number of reasons including reduced reagents required, small footprint, potential for IC integration and increased precision of reactions, to name a few. Included among the requirements for such devices is the ability to transport or pump reagents or reaction products, the ability to effectively mix small volumes of fluid and provide direct data display. Surface acoustic wave (SAW) driven acoustic streaming generated by a piezoelectric material represents a developing solution to many of the demands of these devices with advantages over other pumping and mixing schemes. In this study, the piezoelectric material chosen is 128˚ Y-Cut, X-Propagating LiNbO3. Most studies of this material limit their focus to the X-direction as it is the direction of pure Rayleigh SAW propagation. However, annular and curved structures rely on operation along other crystal orientations. Such designs are promising in that they focus the acoustic energy resulting in increased streaming effects which translate to more effective mixing and pumping. In the work presented here, simulations of the material's response have been conducted using COMSOL Multiphysics® software to help drive the design of prototype SAW devices. Included in these simulations are surface wave features and in particular vertical components of the displacement field (Figure 1), as this is the component of the wave which couples most strongly with the fluid, as well as complex admittance values derived from the simulations (Figure 2). The study of this material is not limited to the X-direction but also includes other orientations (Figure 3) of wave propagation over the surface since some of the prototype devices utilize annular/curved electrodes. These simulations are compared to measurements including off X-axis acoustic streaming velocities generated from prototype SAW devices (Figure 4) fabricated in the CNSE cleanroom.

Figures used in the abstract

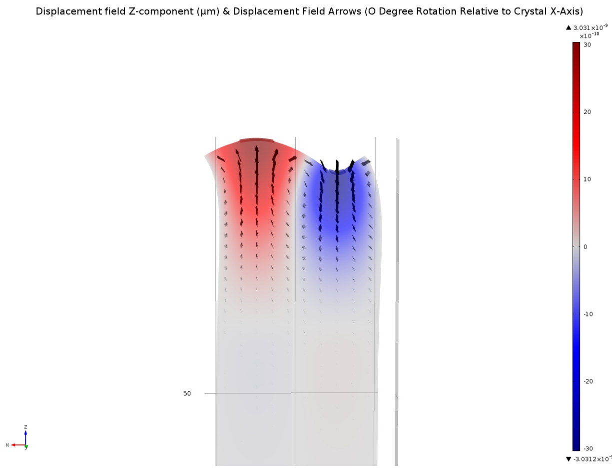

Figure 1: Vertical displacement and displacement field arrows for Rayleigh SAW mode in crystal X-axis.

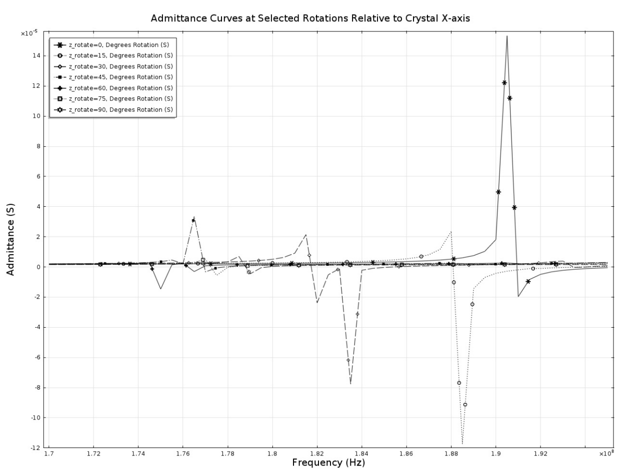

Figure 2: Admittance values for angles of 0 to 90 degrees rotation from the crystal x-axis in 15 degree increments.

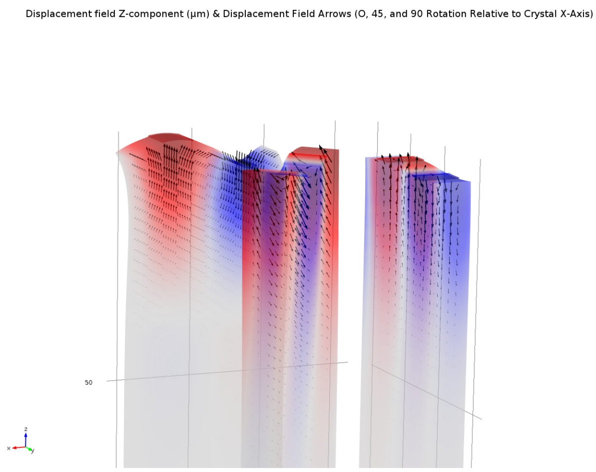

Figure 3: Vertical displacement and displacement field arrows for 0, 45, and 90 rotations at respective resonant frequencies.

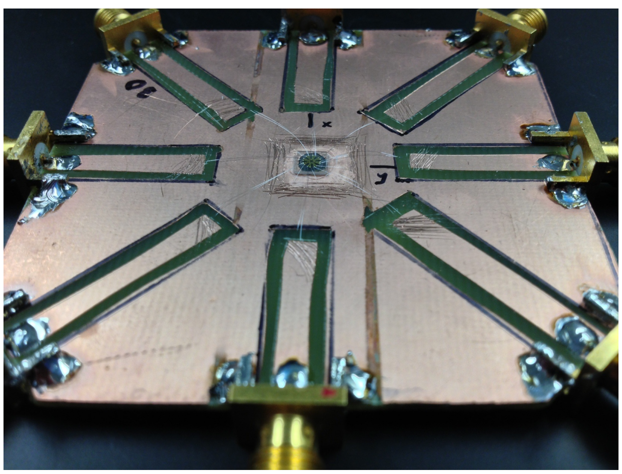

Figure 4: A fabricated SAW test structure used for experimental verification.