Finite Element Simulation of Love Wave Based SAW Delay Line Using COMSOL Multiphysics

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Abstract

INTRODUCTION: A Surface acoustic wave (SAW) device consists of metal interdigital electrodes (IDT) made over the piezoelectric substrate. Application of sinusoidal voltage to the IDT launches an elastic wave on the surface due to inverse piezoelectric effect [1, 2]. SAW can be a promising bio-sensing platform but the conventional Rayleigh wave based SAW devices have vertical particle displacements which leads to attenuation in liquid media [3]. To avoid this problem, SAW devices are required which generate in-plane shear-horizontal wave motion such as the Love wave (LW) devices [4]. A LW device consists of a waveguide layer coated over the substrate generating a leaky SAW [5, 6].
USE OF COMSOL MULTIPHYSICS: The 3D geometry used for simulation in COMSOL Multiphysics along with time response snapshots are shown in Figure 1. The desired orientation of 36°−YX Lithium Tantalate (LT) is obtained through rotated coordinate system. The device operates at lambda = 12 um. The input and output IDTs of electrode width lambda/4 are made over the substrate. A 4.7 um thick SiO2 film is considered as wave guiding layer. Periodic boundary condition (PBC) with continuity is assumed along z axis which effectively makes the IDTs of infinite aperture [7]. A critically damped region of size 2*lambda is made near the boundaries so that there are no reflections from the edges. A sinusoidal voltage of Vin = 5sin(2pift) V, with f = 325 MHz is applied to the input IDT. The simulation is run for 50 ns with a time step of 0.01 ns. Thin PMMA layer is put over the delay region to simulate mass loading. Time response simulation in the MEMS model is performed to compute time delay and phase shift with respect to the plain surface and used to compute the phase mass sensitivity of the device [8]. The insertion loss (IL) of the device is obtained by taking the Fourier transform of the system's impulse response.
RESULTS: The in-plane horizontal displacements are much larger compared to vertical displacements which confirm the shear-horizontal wave nature of LW (Figure 2). The voltage at the output IDT starts to rise in about 15.5 ns which give a Love wave phase velocity of 3850 m/sec. The Love wave device offers a phase mass sensitivity of 88.03 m2/kg (Figure 3). The delay line gives insertion loss of -32.2 dB and loading the device with 200 nm thick PMMA layer generates an additional loss of about 0.25 dB (Figure. 4).
CONCLUSIONS: The paper has presented finite element simulation of Love wave based SAW delay line device comprising of 36°−YX LT substrate with SiO2 guiding layer. Typically delay line simulation requires large geometry and memory usage but using PBC in COMSOL

Multiphysics aids to keep the geometry small. Time response simulation of LW delay line is performed to calculate output voltage, displacements, mass sensitivity and IL. The mass sensitivity value obtained is consistent with previously reported values [9, 10]. Love wave devices are very important for designing bio-sensors and simulations in COMSOL Multiphysics help to obtain the device characteristics prior to actual fabrication.

Reference

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Figures used in the abstract

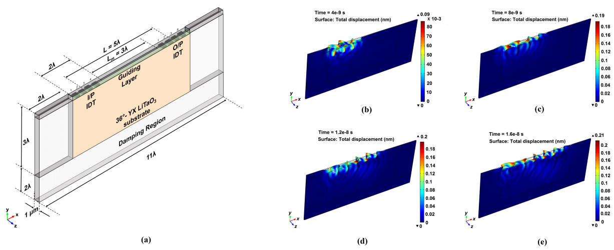

Figure 1: (a) Simulation Geometry of the device. (b) Snapshots of time response of LW delay line at (b) 4 ns (c) 8 ns (d) 12 ns and (e) 16 ns.

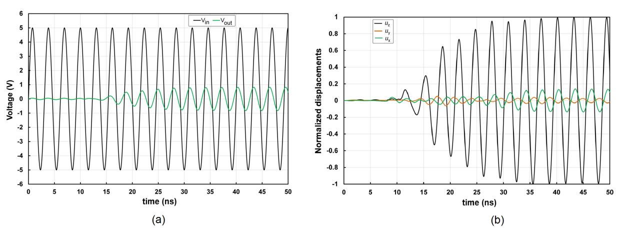

Figure 2: (a) Variation of input and output voltage with time. (b) Plot of normalized displacements ux uy and uz at the output IDT with time.

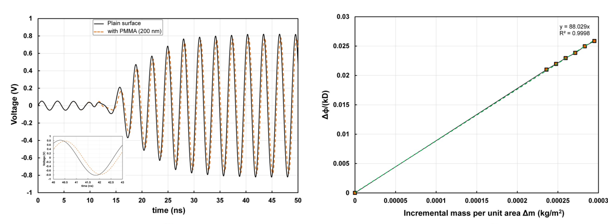

Figure 3: (a) Plot of output voltage versus time for the plain surface and 200 nm thick PMMA loaded surface. Inset shows the time delay between two waveforms. (b) Plot of normalized phase shift (delphi/kD) versus incremental mass per unit area (deltam). The slope of the straight line represents the phase mass sensitivity.

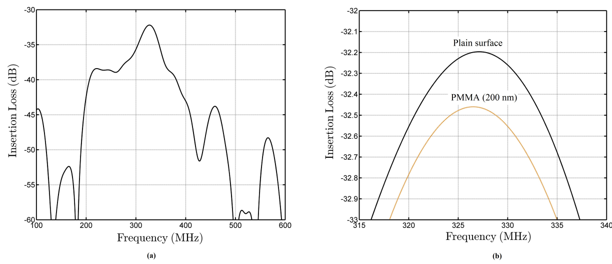

Figure 4: (a) Insertion loss of delay line. (b) Insertion loss due to PMMA mass loading.