Electrode Design For Efficient Excitation Of Vibrational Modes In An AlN Based PMUT

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Abstract

Piezoelectric micromachined ultrasound transducers (PMUTs) are gaining increasing interest as miniaturized, low-power devices which can be easily integrated with electronic systems for applications such as medical imaging, therapeutic ultrasound, and particle manipulation.

This work investigates electrode design for efficient excitation of different vibrational modes in a single PMUT. Optimal electrode configurations for the first 4 vibrational modes are obtained by performing a nested sweep in a frequency domain study in COMSOL Multiphysics®. First, different electrode configurations are proposed for each vibrational mode. Second, electrode dimensions and excitation frequency are swept for each electrode configuration to determine resonance frequencies and to extract the optimal electrode dimensions by computing the normal displacement of the vibrating membrane. Finally, the optimal electrode design for each vibrational mode is obtained by comparing the results for each electrode configuration.

The simulations couple the solid mechanics, electrostatics and pressure acoustics interfaces via the piezoelectric effect and an acoustic-solid boundary. An axisymmetric model is built for modes (0,1) and (0,2) due to the axial symmetry of the modes and the involved physics. A 3D model is built for modes (1,1) and (2,1) which includes symmetry planes such that only one quarter and one eighth of the device needs to be simulated, respectively.

Simulation results for the fundamental vibration mode are validated by experimental data on fabricated aluminium nitride based PMUTs. The out-of-plane displacement of these devices is characterized by laser Doppler vibrometry using a Polytec MSA500. Measurements are carried out over a range of electrode dimensions to compare experimental data with numerical simulations.

The results of this work may provide insight into efficient excitation of vibrational modes and electrode design for higher mode or multifrequency PMUTs.

Figures used in the abstract

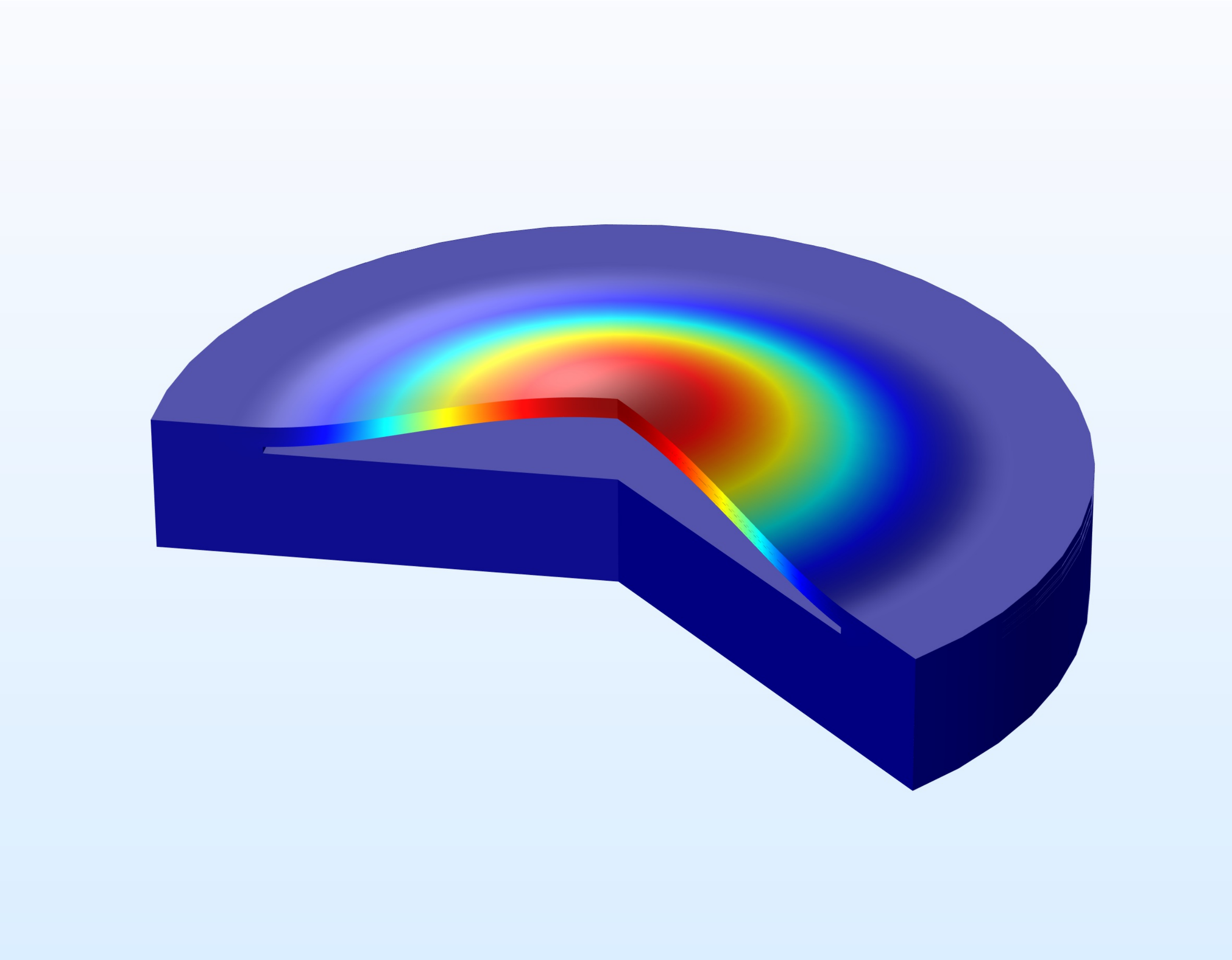

Figure 1 : Simulated deformation and stress of a reference PMUT at resonance frequency for vibration mode (0,1).

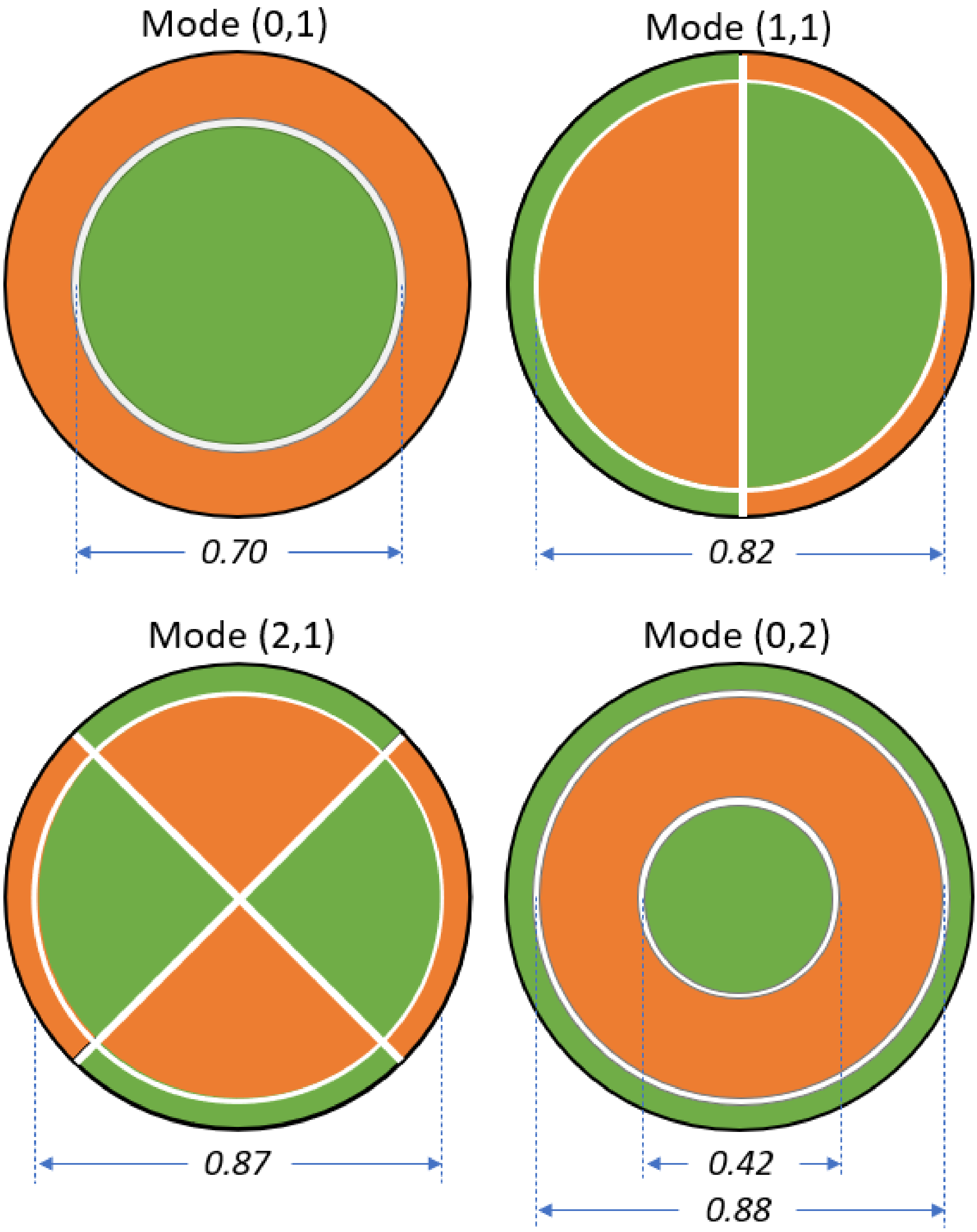

Figure 2 : Optimized top electrode designs for the first 4 vibration modes. The green and orange regions denote electrodes which are actuated out-of-phase.

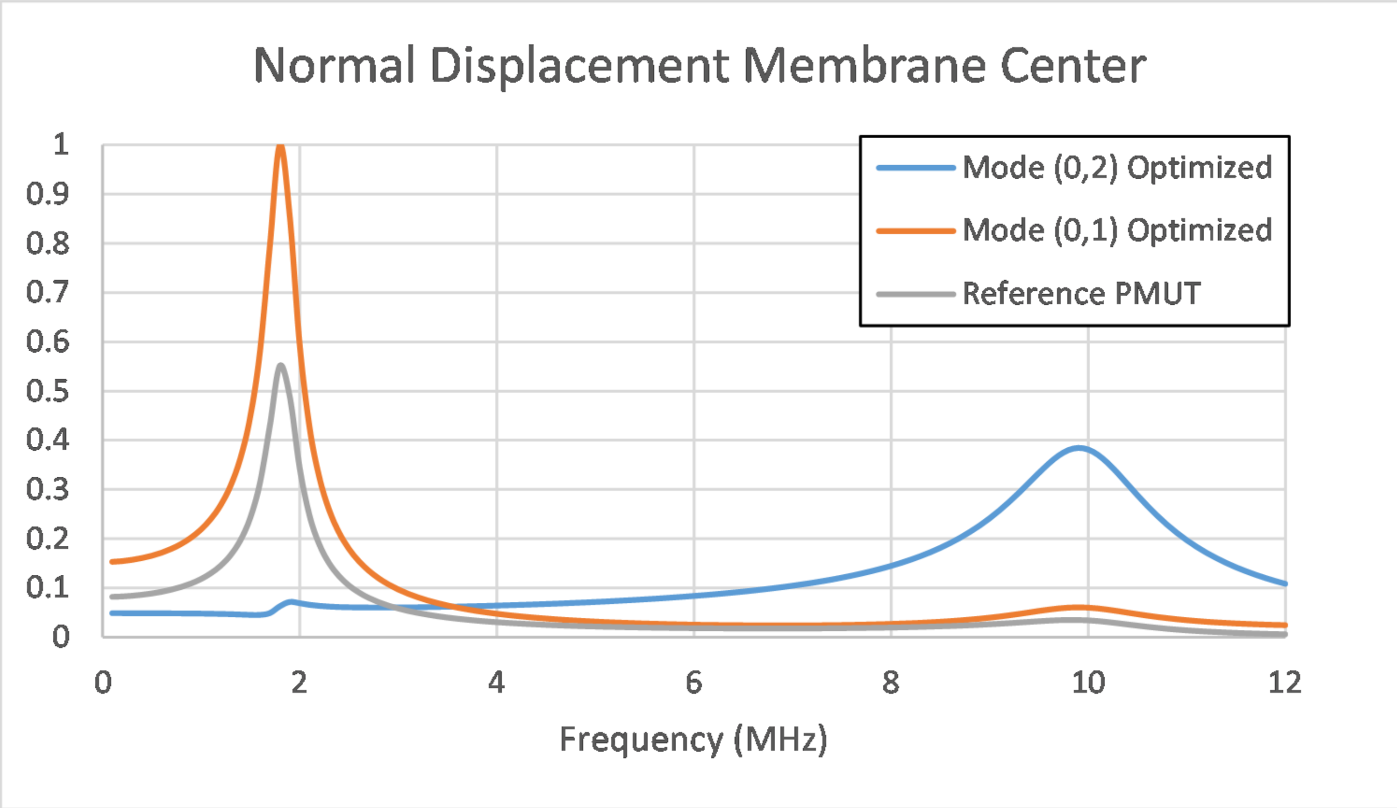

Figure 3 : Simulated normal displacement of the center of the membrane (axisymmetric modes). Optimized designs are compared to a reference PMUT.

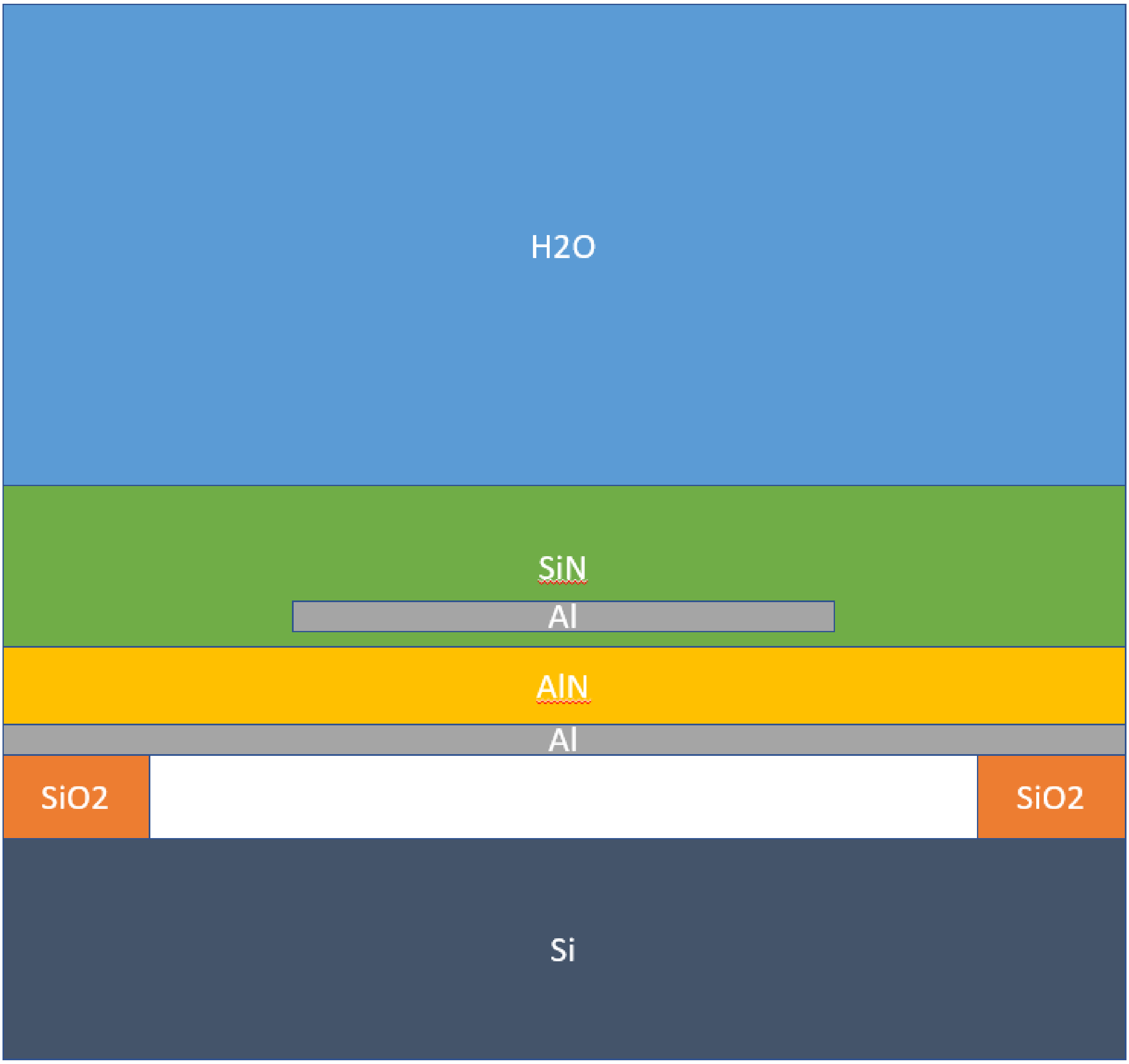

Figure 4 : Material stack used in the simulations.