Electrode Optimization for Multi-Channel Piezoelectric Micromachined Ultrasonic Transducers

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Piezoelectric Micromachined Ultrasonic Transducers (PMUTs) are being researched for various ultrasound applications with specifications such as wide operating frequency and bandwidth addressed for versatility and measurement precision. In contrast to most prior research focusing on single-mode PMUTs, this study presents a device featuring designs optimized for multi-modal operation. The device demonstrates balanced sensitivity and expanded bandwidth across the first five modes, enhancing performance for applications such as wireless telemetry [1]. A multi-channel PMUT link demonstrates flexible mode selection and combinational operation over a frequency range from 464 kHz to 4.3 MHz.

Description

The PMUTs, fabricated using an AlN-on-SOI platform, were subject to numerical and analytical simulations to develop an electrode pattern that optimizes sensitivity across the first five modes when driven simultaneously. The TX and RX designs, as illustrated in Figure 1, aim to effectively utilize the first three symmetric modes and two asymmetric modes. The TX electrode pattern is specifically optimized to balance drive sensitivity by considering strain polarity and phase cancellation. To address the reduced acoustic output from the asymmetric modes, the design incorporates two supplementary PMUTs, each tuned to the resonant frequencies of the asymmetric (1,1) and (1,2) modes. Conversely, the receiver's (RX) design focuses on maximizing electromechanical coupling efficiency across first five modes.

Experimental Results

Experimental validation was conducted in an airborne test setup with a 10-15 mm separation between the PMUT transmitter and receiver. The TX, driven at 10 V_{pk}, has its resonant frequencies recorded corresponding to different modes at 464 kHz, 950 kHz, 1.78 MHz, 2.31 MHz, and 4.28 MHz, with results captured using a Digital Holographic Microscope (DHM), as displayed in Figure 2. The RX detected all five modes, demonstrating comparable sensitivity. The balanced sensitivity between TX and RX enables the operation of each mode as independent channels, with the carrier frequency matched to the resonance. A waveform combining selections from the first five modes was generated and used to drive the multi-mode PMUT TX. The RX effectively discerned the complex signal, validating the effectiveness of the proposed design for multi-mode operation.

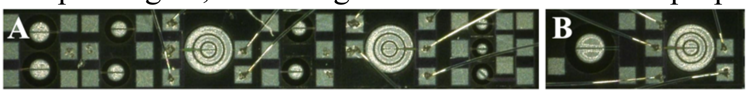

Figure 1. Optical micrographs of optimized multi-channel PMUT A: TX; and B: RX.

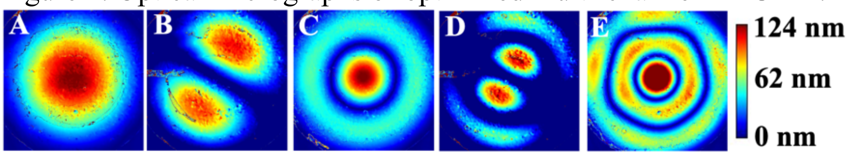

Figure 2. A-E: Experimentally measured vibration profiles of first 5 modes from 464 kHz to 4.3 MHz.

[1] T. Zhang and A. Seshia, "Multi-mode piezoelectric micromachined tranducers for multi-channel acoustic power transfer and data telemetry," in *2023 22st International Conference on Solid-State Sensors, Actuators and Microsystems (Transducers)*, Kyoto, Japan, 2023.