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Selectable Frequency CMUT with Membrane Stand-Off Structures

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Background, Motivation and Objective

Microbubbles are currently used to enhance ultrasound image contrast and are being considered for use in therapeutic applications such as drug delivery. These functions drive the desire to produce ultrasound transducers that are capable of both high-frequency, high-sensitivity operation for imaging and low-frequency, high-intensity output for bubble-related therapy. Designing a single device to operate at these disparate frequencies – as low as 1MHz to excite bubbles and as high as 40MHz to permit high resolution Intravascular Ultrasound (IVUS)-based imaging – presents a significant challenge.

Research in the area of capacitive micromachined ultrasonic transducers (CMUTs) has demonstrated a membrane-collapse mode of operation that allows a collapsed membrane to operate at approximately double its non-collapse frequency. Through the use of validated finite element analysis (FEA) simulations, we demonstrate the feasibility of implementing partial-height stand-off structures within the device vacuum-gap that divide the device membrane into smaller, higher-frequency sub-membrane structures on membrane collapse in order to produce higher-order shifts in frequency than have been previously reported.

Statement of Contribution/Methods

Extending the proven concept of collapse-mode operation of CMUT devices in this manner contributes to the state of the art in MEMS-based ultrasound and allows the standard operation mode and collapse mode resonances to be designed independently. Simulations were verified against a CMUT fabricated at the University of Virginia Microfabrication Laboratory (UVML) with a correlation coefficient of 0.92 and an amplitude error of 4.1%. Fabrication procedures closely followed previously published techniques. Each CMUT membrane within the device measured 50µm by 250µm, was 2.2µm thick, and was suspended 0.30µm above an insulated substrate electrode.

The proposed stand-off configuration, consisting of three stand-off structures, was modeled using PZFlex (Weidlinger Associates, Inc., Mountain View, CA). An optimization was performed to eliminate out-of-phase motion of the collapsed membrane structures by accounting for the dynamics of the collapsed membrane.

Results

The optimum spans for each of the four sub-membranes as a percent of the total span are 31.8% for the central sub-membranes and 18.2% for the lateral sub-membranes. A hybrid device designed to operate at both 1.5MHz and 40MHz has been shown in simulation to posses comparable bandwidth to each of two single-frequency CMUTs operating at 1.5MHz and 40MHz, respectively, suffering a reduction in output intensity of only 4.0dB and 4.5dB, respectively.

Discussion and Conclusions

These results suggest the feasibility of the selectable-frequency CMUT with minimal impact on performance. Future work involves fabrication of the proposed devices, already underway at the UVML. Fabricated devices will be characterized and these data will be used to validate the FEA.