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An Architecture and Fabrication Process for High-Efficiency Charging-Free CMUTs

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Background, Motivation and Objective

Capacitive micromachined ultrasound transducers (CMUTs) are a promising alternative transducer technology with potential for highly integrated electronics. However, reliability issues associated with dielectric charging and operational hysteresis generally restrict device operation to pre-collapse modes far from collapse biasing, resulting in poor efficiency. Several efforts have been made to address these issues, however charging and hysteresis remain a barrier to widespread adoption of CMUT technology. Recently, our group proposed so-called isolated isolation posts (IIPs). These IIP-CMUTs were effective in preventing long-term dielectric-charging and hysteresis but owing to variability in membrane collapse voltages, elements had low electromechanical efficiency. Moreover, these devices were prone to electrical breakdown due to trapped particles, encountered inconsistencies between membrane snap-down voltages across elements, and had yield issues. This work seeks to address these issues while maintaining long-term reliability.

Statement of Contribution/Methods

We demonstrate a wafer-bonded fabrication process for IIP-CMUTs that avoids pre-charging of dielectrics due to plasma etching, avoids oxide cusps that lead to bond voids, and better insulates device areas prone to breakdown. This process was used to fabricate long rectangular CMUTs with high electromechanical efficiency from highly doped SOI wafers. Both IIP-CMUTs and regular CMUTs with contiguous dielectrics were fabricated for comparison purposes. Electrical characterization was performed using a semiconductor characterization system, while membrane deflection and resonance frequency were analyzed using a laser Doppler vibrometer.

Results/Discussion

Fig. 1a shows the cross-section of fabricated IIP-CMUTs. Fig. 1b shows a helium ion image of an IIP-CMUT with a cut membrane. Fig. 1c shows C-V data of an IIP-CMUT operated past the snap-down voltage for 200 consecutive cycles without charging. Fig. 1d shows vibrometer data for a rectangular CMUT excited with a 5 V CW signal. Regular rectangular CMUTs were found to have electromechanical efficiency greater than 0.95. Results are promising for fabrication of hysteresis-free high-efficiency CMUTs with reliable operation.