Large-Scale Multi-Gap Multi-Frequency CMUT Arrays

Mohammad Maadi and Roger Zemp.
Electrical and Computer Engineering Department, University of Alberta, Edmonton, Alberta, Canada

Background, Motivation and Objective

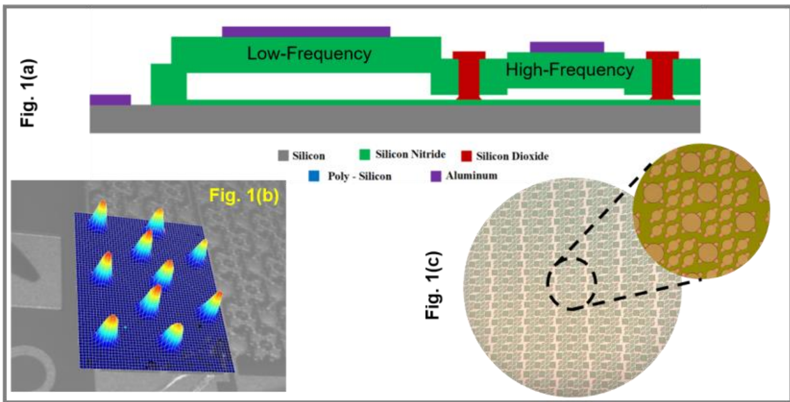
Most ultrasound transducers operate with a limited bandwidth, minimizing opportunities for multi-depth and novel harmonic imaging applications. Recently, we introduced multi-frequency CMUT arrays where large-membranes, sensitive to low-frequencies, were interlaced amongst small membranes, sensitive to high-frequencies. The interlacing could be achieved on a scale smaller than acoustic wavelengths, thus mitigating side-lobes. However, previous designs had limited transmit power at low-frequencies owing to low-collapse voltages. To achieve higher transmit power levels, we introduce multi-gap multi-frequency CMUT arrays. The large, low-frequency membranes are fabricated with a larger gap, thus enabling higher operating voltages without collapse, and providing a larger range of membrane motions.

Statement of Contribution / Methods

Multi-frequency CMUT arrays were fabricated using a modified sacrificial release process. Compared to previous multi-frequency devices, an additional mask step was added for separate patterning of large membranes to achieve a larger gap. High-frequency membranes ranged from 12-15 microns radius (8-15MHz in immersion), and low-frequency membranes ranged from 25-30 microns radius (~2MHz center frequency in immersion). Different sized arrays with 64 and 128 channels for each of the low- and high-frequency sub-arrays were fabricated. Accurate nonlinear CMUT models were used to predict the improvement in transmit pressures.

Results / Discussion

Previous multi-frequency devices produced peak-to-peak output pressures at 2MHz as high as 0.8MPa. By increasing the gap height from 400 to 800 microns and the membrane thickness from 1 to 1.5 microns, the membrane velocity (when biased at 80% of the collapse voltage) and driving at 30V AC (rather than the previous limit of 3.5V AC), we predicted a 3.5 times improvement in output pressure. Current multi-frequency devices were tested for multi-frequency imaging by connecting to a Verasonics ultrasound platform to demonstrate multi-scale imaging. Wire phantom resolution measurements at 17mm imaging depth demonstrated lateral spatial resolution of 0.87mm using the high-frequency sub-array and 0.31mm using the low-frequency sub-array. These data show promise for next-generation applications to multi-depth imaging and super-harmonic contrast imaging applications.



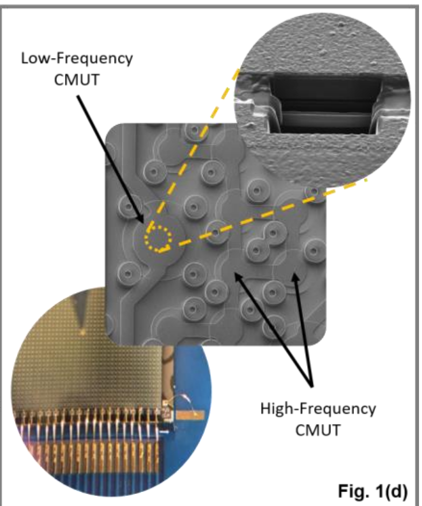


Fig. 1(a). The final cross-sectional overview of multi-gap multi-frequency fabrication scheme using modified sacrificial release process. Fig. 1(b). Sample laser Doppler Vibrometer measurements using current multi-frequency devices. Fig. 1(c). Microscope image of partially-fabricated large-scale multi-gap multi-frequency CMUT arrays. Fig. 1(d). A large-scale multi-frequency CMUT array, wirebonded to a custom PCB circuit for multi-band imaging and helium ion microscope image of current large-scale multi-frequency CMUT arrays.

Fig. 1(d)