High Performance CMUTs with Monolithically Integrated Front-end Electronics for Medical Ultrasound Imaging

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Capacitive micromachined ultrasonic transducers (CMUTs) have emerged as an enabling technology for ultrasound imaging especially for applications requiring highly dense 2-D arrays and miniature arrays requiring high level of integration. A key premise of CMUT technology is that it allows for front-end electronics integration while providing equal or better transduction performance as compared to piezoelectric transducers, the currently dominant transducer array technology. In this talk, we describe our progress towards these goals. We have developed a low-temperature Plasma Enhanced CVD based process to fabricate CMUTs on silicon wafers containing CMOS electronics. We have designed, fabricated, and tested a variety of CMUT arrays for intracardiac and intravascular imaging operating in the 4-60MHz range. These arrays have novel array geometry and front-end electronics structures. We have successfully tested CMUT arrays built on custom designed 0.35u CMOS front-end electronics fabricated at a commercial foundry. In parallel with electronics integration efforts, we have developed CMUT structures with multiple electrodes and non-uniform membranes to improve transduction performance both in transmit pressure level, receive sensitivity and electromechanical coupling coefficient. As a result, today we have CMUTs operating at 8MHz center frequency that can simultaneously achieve 3MPa output pressure, 134% fractional bandwidth and a coupling coefficient, $k^2 = 0.82$ at a DC bias that is 90% of the collapse voltage. These measured performance metrics show that CMUTs can perform at the level of state-of-the-art single crystal piezoelectrics and provide tolerance for array non-uniformity while retaining the manufacturing and electronics integration advantages offered by microfabrication techniques.