Micromachined Ultrasonic Transducers for 3-D Imaging

Real-time ultrasound imaging is a widely used technique in medical diagnostics. Recently, ultrasound systems offering real-time imaging in 3-D has emerged. However, the high complexity of the transducer probes and the considerable increase in data to be processed compared to conventional 2-D ultrasound imaging results in expensive systems, which limits the more widespread use and clinical development of volumetric ultrasound. The main goal of this thesis is to demonstrate new transducer technologies that can achieve real-time volumetric ultrasound imaging without the complexity and cost of state-of-the-art 3-D ultrasound systems. The focus is on row-column addressed transducer arrays. This previously sparsely investigated addressing scheme offers a highly reduced number of transducer elements, resulting in reduced transducer manufacturing costs and data processing. To produce such transducer arrays, capacitive micromachined ultrasonic transducer (CMUT) technology is chosen for this project. Properties such as high bandwidth and high design flexibility makes this an attractive transducer technology, which is under continuous development in the research community.

A theoretical treatment of CMUTs is presented, including investigations of the anisotropic plate behaviour and modal radiation patterns of such devices. Several new CMUT fabrication approaches are developed and investigated in terms of oxide quality and surface protrusions, culminating in a simple four-mask process capable of producing 62+62-element row-column addressed CMUT arrays with negligible charging issues. The arrays include an integrated apodization, which reduces the ghost echoes produced by the edge waves in such arrays by 15.8 dB. The acoustical cross-talk is measured on fabricated arrays, showing a 24 dB reduction in cross-talk compared to 1-D arrays for 2-D imaging. Volumetric imaging is successfully demonstrated using a beamformer specifically developed for row-column addressed arrays. Furthermore, a technique for estimating flow velocities in all three dimensions is presented.

Based on the developed techniques, a complete hand-held 3MHz λ/2-pitch ultrasound probe for volumetric imaging with 62+62 elements and in-handle electronics is produced and used on a commercial bk3000 scanner from BK Medical. The scanner is made for conventional 2-D ultrasound imaging, proving that the developed technology enables real-time volumetric ultrasound imaging with a total system cost and complexity equivalent to that of 2-D ultrasound imaging systems.

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