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**Capacitive micromachined ultrasonic transducers for generation of highly directional sound with a parametric array**

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Capacitive micromachined ultrasonic transducers (CMUTs) with vacuum-sealed cavities have been fabricated and used to project directional sound using parametric arrays. The wafer bonding approach used to fabricate the CMUTs provides good control over device dimensions, a single-crystal silicon membrane that has predictable mechanical properties, and the capability to fabricate CMUTs with large-diameter membranes and deep cavities. The fabricated CMUTs are about 8 cm in diameter and comprise 284 circular membranes, each 4 mm in diameter. Testing of CMUTs with 40- $\mu\text{m}$  and 60- $\mu\text{m}$ -thick membranes shows they have center frequencies of 46 kHz and 55 kHz and 3-dB bandwidths of 1.9 kHz and 5.3 kHz, respectively. With application of DC bias voltages of 380 V and 350 V and an AC excitation of 200 V peak-to-peak, the devices generate effective source levels of 139 dB and 131 dB (re 20  $\mu\text{Pa}$ ), respectively. We used the CMUT design with a 60- $\mu\text{m}$ -thick membrane to produce 5 kHz sound at 3 m with a 6-dB beamwidth of 8.7 deg and a sound pressure level of 58 dB. The results demonstrate that large-area CMUTs, which produce high pressure ultrasound, can be fabricated for transmitting directional sound with parametric arrays. [Work supported by DARPA.]