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Adhesive Wafer-Bonding Fabrication of Flexible Capacitive Micromachined Ultrasound Transducers with Silicon Nitride Membranes

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Background, Motivation and Objective

Flexible ultrasound transducers may offer new frontiers for wearable medical ultrasonic technologies including applications such as cardiac output monitoring, sensing of blood flow in emergency settings, and therapy monitoring. We utilize capacitive micromachined ultrasound transducers (CMUTs) due to their receive sensitivity and bandwidth when compared to piezoelectric transducers. While CMUTs are typically fabricated on a rigid structure such as silicon, flexible CMUTs fabricated with polymer membranes have been reported. However, polymer membranes present long-term performance issues including loss of hermeticity due to gas diffusion. Thus, we focused on designing flexible CMUTs with silicon nitride membranes.

Statement of Contribution/Methods

To fabricate flexible CMUTs, we sputtered chromium and aluminum onto low pressure chemical vapor deposited (LPCVD) silicon nitride to create bottom electrodes. Photosensitive benzocyclobutene (BCB) was then spin coated on the bottom electrodes to create an adhesive layer. A structural layer of BCB was then spin coated and patterned onto a separate LPCVD silicon nitride wafer, creating cavities less than 50 µm in diameter with sub-micron depth. Adhesive wafer bonding was used to bond the BCB, creating vacuum cavities. Reactive ion etching and KOH were used to remove the silicon nitride layer and silicon handle respectively. A flexible substrate was then applied and another layer of aluminum was sputtered and patterned to create top electrodes. To demonstrate functionality, we utilized a semiconductor characterization system to measure the C-V response in air. Additionally, a ZYGO Optical Profilometer was used to measure the deflection of the membranes under different bias voltages.

Results/Discussion

Fig. 1(a) is of the finished CMUT die being bent. Fig. 1(b) displays the deflection of the membranes due to a DC bias. Fig. 1(c) is the deflection vs DC bias profile. Fig. 1(d) is the C-V response, demonstrating device functionality. These results demonstrate the feasibility of our fabrication process and potential applications in emerging wearable ultrasonic devices.

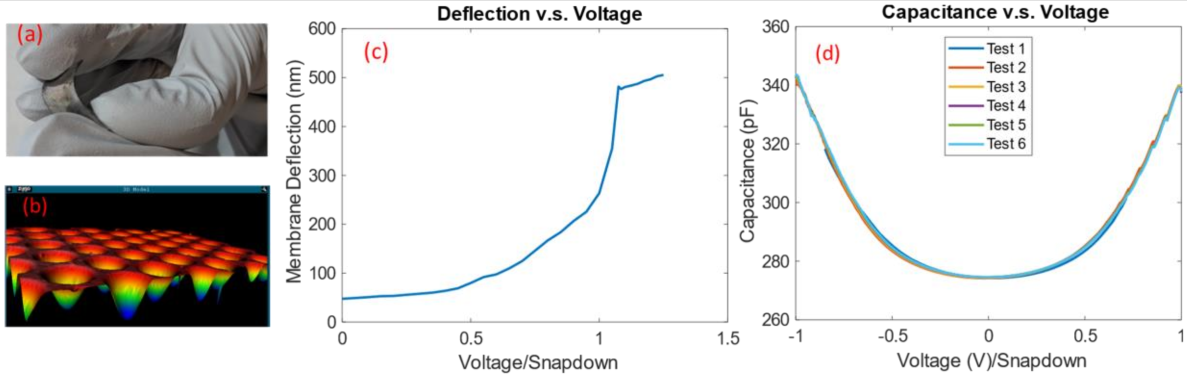

Fig. 1 (a) Bent flexible CMUT die (b) 3D surface profile of membrane deflection taken with ZYGO Optical Profilometer (c) Deflection vs DC bias profile (d) C-V Response of CMUT taken with Keithley Semiconductor Characterization System