Docket #: S11-214

(1) An improved method for operating CMUTs under high and varying pressure, and (2) Production of pre-charged CMUTs for zero-external-bias operation

Stanford researchers have developed two related inventions which advance the state-of-the-art of CMUT's (capacitive micromachined ultrasonic transducers).

The first part of the invention is a new operational mode for CMUTs, in which the plate is in permanent contact with the bottom of the cavity, even at zero DC bias and 1 atm pressure. This operational mode provides more stable resonant frequencies, and an improved coupling efficiency at lower DC bias voltages, in an environment with high and varying pressure (~1-20 atm).

The second part of the invention comprises a CMUT structure with a partial electrode, which surrounds a floating island. This structure is advantageous for both the proposed new operational mode with plate in permanent contact (reduces breakdown and improves device reliability; reduces the parasitic capacitance associated with the permanently contacting area, allowing improvement of the coupling efficiency at higher pressure) as well as the conventional operational mode (the device can be pre-charged to realize dc bias-free operation). Bias-free CMUT's will be applicable to medical imaging, such as 3D/4D real-time ultrasonic imaging, intracardiac ultrasound imaging, and 3D photoacoustic functional imaging.

Stage of Research:

The CMUTs in the permanent contact operation mode has been successfully fabricated and validated using finite element analysis (FEA).

Devices have been characterized by measuring their electrical input impedance (1-20 atm) and displacement profile.

Pitch-catch operation has been demonstrated up to 20 atm pressure.

Some CMUTs in the conventional mode have been precharged to demonstrate bias free pitch catch. And the charge stays stable for > 1.5 years.

On-going Research:

The future work includes further simulation (FEA, transient) and characterization.

Applications

- **Invention 1**: The proposed permanent contact operational mode greatly benefits any applications with larger or varying pressure, or mechanical force, on the transducer surface. Examples include:
  - **Medical and therapeutic devices**, where mechanical push on the transducers is possible,
  - **Ultrasonic flow metering (UFM)**
  - Any other applications requiring the ultrasonic transducers to function under high and varying pressures, such as **chemical sensing, range finding, and non-destructive evaluation in harsh environments.**
- **Invention 2**: The external-bias-free CMUTs allowed by the partial electrode structure will be of great interest to any CMUT applications, especially those requiring small battery or low external DC biasing. Examples include but are not limited to all types of **ultrasound based medical imaging applications, such as 3D/4D real-time ultrasonic imaging, intracardiac ultrasound imaging, and 3D photoacoustic functional imaging.**

Advantages

- **Invention 1**: ***Permanent contact operational mode***:
  - More stable frequency, static operational point, and improved coupling efficiency
  - No pre-collapsed voltage required

    - Instead of sacrificial release process, the wafer bonded plate gives more design flexibility especially for large devices for UFM applications
- **Invention 2**: ***Partial electrode for permanent contact devices***:
    - Donut-shaped partial electrode can further stabilize the performance and improve it at higher pressures
    - Less breakdown
    - Less parasitic and thus improved coupling efficiency
- **Invention 2**: ***Partial electrode for conventional devices***:
    - External-bias-free CMUTs – the not-connecting central part of the electrode allows for the possibility of pre-charging the devices with high DC voltage. The charges trapped in this de-activated part of the electrode can provide the internal DC bias necessary for later conventional operations, thus creating the external-bias-free devices.

Publications

- M.-C. Ho, M. Kupnik, K. K. Park, and B. T. Khuri-Yakub, "*Long-term measurement results of pre-charged CMUTs with zero external bias operation,*" presented at the IEEE Ultrasonics Symposium, Dresden, Germany, Oct. 7-10, 2012.
- M.-C. Ho, M. Kupnik K. K. Park, K. Eckhoff, and B. T. Khuri-Yakub, "*Wide pressure range operation of air-coupled CMUTs,*" presented at the IEEE Ultrasonics Symposium, Dresden, Germany, Oct. 7-10, 2012.
- M.-C. Ho, M. Kupnik, S. Vaithilingam, and B. T. Khuri-Yakub1, "*Fabrication and model validation for CMUTs operated in permanent contact mode*" presented at the IEEE Ultrasonics Symposium, Orlando, FL, Oct. 18-21, 2011.
- M.-C. Ho, M. Kupnik, and B. T. Khuri-Yakub, *"FEA of CMUTs suitable for wide gas pressure range applications,"* presented at the IEEE Ultrasonics Symposium, San Diego, CA, Oct. 11-14, 2010.

Patents

- Published Application: 20130087867
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