Piezo MEMS Transducers, Ultrasonic Transducer for Distance Measurement

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CSEM is developing a miniaturized piezoelectric micromachined ultrasonic transducer chip for industrial applications in distance and proximity sensing.

Ultrasonic distance and proximity sensors for industrial automation have basically been built for decades with transducers made of a piezoelectric disc and a matching layer. The latter is used to increase the amplitude of the piezoelectric disc in order to transmit enough sound energy into the air. One speaks also of adaption of acoustic impedance from the hard piezo ceramics to the soft air. The sound is very much attenuated then in the air path, reflected by a target and finally received by the very same transducer. The sensor switches between transmitter and receiver mode. The main advantages of ultrasonic sensors over other sensing technologies are:

- Sensing independent of material, surface, color, size
- Works under dust, dirt, fog, and difficult lighting conditions
- Detection of transparent and bright objects
- Wide measuring range from mm up to 5m

MEMS-based ultrasonic transducers have gained attention in the last 10-15 years in particular through academic research. Currently two technologies have been established, known as capacitive micromachined ultrasonic transducers (CMUT) based on electrostatic actuation, and piezoelectric micromachined ultrasonic transducers (PMUT) based on thin film piezoelectric actuation. Our development is based on PMUT technology since CSEM has a lot of expertise in this domain.

The scientific goal of this project is to have rugged ultrasonic proximity sensing at least for 50 mm distance. Typical applications are target detection in automated production and packaging machines and robots as well as level measurement in narrow cavities such as, *e.g.*, medical test tubes or liquid medicine containers (ampoules). Furthermore, consumer goods such as coffee machines (filling level adjusted to coffee cup) and professional laser printers (web guide control) would benefit from low-cost miniature ultrasonic sensors once the technology is mature.

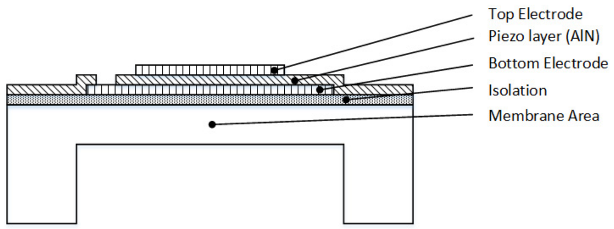

Figure 1: Schematic cross-section of the MEMS transducer device.

The focus in this project is not only on high sound pressure but also on very sensitive reception and few crosstalk within a MEMS unit. The main challenge with MEMS-based ultrasonic transducers to be addressed in this project is related to the reduced transmission power due to reduced transducer size, compared to bulk piezoelectric discs. The lack of transmission power has to be compensated by a very efficient conversion of input power to ultrasound emission, and on the receiver side by a highly increased sensitivity. Both aspects have been investigated and optimized by COMSOL multiphysics modeling.

A schematic cross section of the basic MEMS transducer / receiver element is shown in Figure 1. The fabrication process is relatively simple and requires only 4 mask layers. The transducer element consists of a bimorph membrane formed by a passivated silicon membrane and a polycrystalline piezoelectric AlN layer with top and bottom electrodes. When applying a voltage between top and bottom electrodes, the polycrystalline piezoelectric AlN layer is subject to dimensional changes in lateral (horizontal) direction. The bimorph of AlN layer and silicon results finally in a vertical buckling of the membrane when excited.

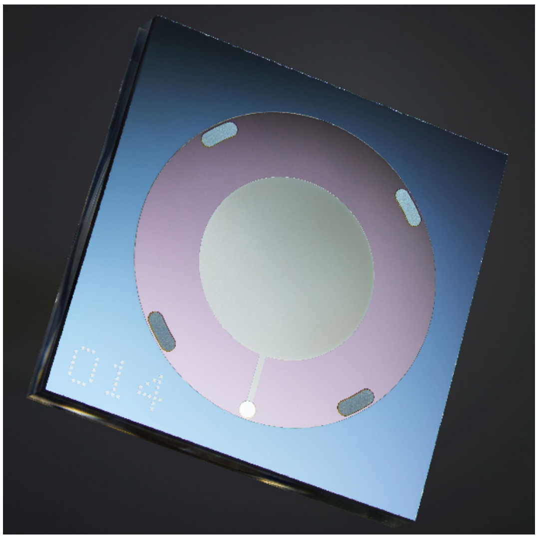

Figure 2: Picture of the MEMS chip. The outer dimensions are 5x5 mm², and the membrane has a diameter of 3.5 mm.

A picture of the device is shown in Figure 2. The MEMS chip measures 5x5 mm², and the membrane has a diameter of 3.5 mm. Measurements based on an optical white light profilometer show a membrane displacement of 1 µm at a resonance frequency around 154 kHz and a driving voltage of 50 V. Currently the device is being characterized by the implementation partner. Preliminary results show a sensitivity well beyond the target value.

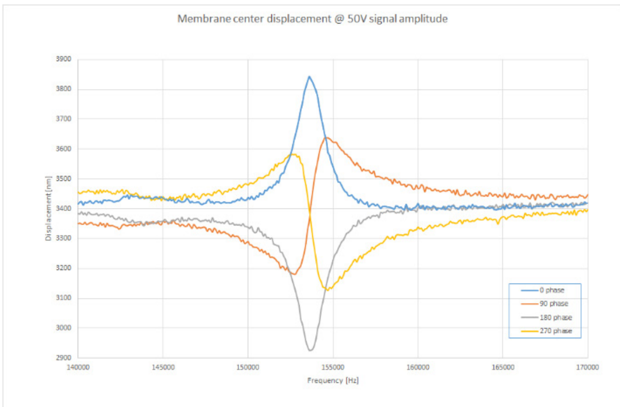

Figure 3: Preliminary measurements using a white light optical profilometer show a membrane amplitude of 1 µm at a resonance frequency close to 154 kHz.