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Characterization of a Piezo-Resistive MEMS Microphone for Aero-Acoustic Measurements

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Summary:

This paper presents the packaging and characterization of a piezo-resistive (PR) micro-electro-mechanical system (MEMS) microphone for aero-acoustic measurements with three different membrane sizes. The thickness of the square membranes is 5 µm with an edge length of 1900 µm, 2260 µm and 2660 µm, respectively. The results of the sensors characterization show a sensitivity of up to 55 dB re 1 V/Pa when exposed to an acoustic chirp signal ranging from 5-50 kHz at 70-100 dB SPL. This paper presents a test approach necessary for chips with very thin membrane and the results of a dynamic pressure frequency response test.

Keywords: aero-acoustic, thin membrane, microphone, piezo-resistive, MEMS

Introduction

The development of new airplane generations with less noise emission and aerodynamic drag can only be enabled by novel finite element simulations, which lack of sufficient accurate calibration data in the past. This desired data can only be obtained by new aero-acoustic microphone sensor systems with high spatial resolution and dynamic range [1]. Available microphones either are packaged in large cases, which inhibits a small pitch between sensors and so a high spatial resolution, or have a low total harmonic distortion, which disables the use in flight tests, where pressures up to 175 dB SPL need to be measured. The thin and flexible array with custom designed PR MEMS microphones, presented by the author in a previous paper [2], addresses the above stated limitations. The focus of this paper is a test approach for chips with a very thin membrane and presents the results of a dynamic pressure frequency response test.

Piezo resistive microphone

The microphone consists of a 5 µm thin square membrane with the three edge lengths (1900/2260/2660 µm). The implanted piezo resistors which are configured to form a Wheatstone bridge, change their resistivity when the membrane is deflected. he membrane has an optional 10 µm ventilation hole, to release static pressures in the back chamber. A schematic drawing of the sensor is shown in Fig. 1, the detailed fabrication steps were descripted in [2].

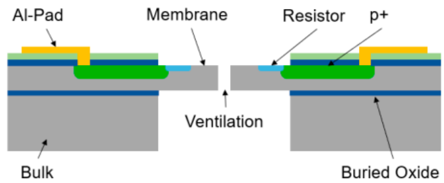

Fig. 1. Structure of the sensor chip shown in a cross-section view (not at scale)

Preparation of the Samples

To measure the response of the fabricated sensor chips dynamic pressure in test benches, it needs to be mounted on a printed circuit board (PCB) sealing the back cavity from the applied pressure. Thermomechanical stress due to different coefficients of thermal expansion of die and PCB can easily preload the thin membrane and so alter the measurement results. When using a very soft or thick applied adhesive, the structure gets to instable for wire bonding. The applied ultrasound is absorbed by the adhesive and does not form the joint of wire and pad. To prevent these effects a silicon adapter chip with a feed-through is firstly glued on the package, using epoxy resin. Then the sensor is attached with a silicone adhesive that is cured at 150 °C. This setup (Fig. 2). does work for aluminium-wire-bonding and the membrane does not get deflected, which can be detected with an optical microscope.

Measurement Setups

The dynamic pressure test was carried out in an anechoic chamber containing the electrostatic pressure source type PID 604142, one sample and an optical reference microphone type Eta250 Ultra. The distance between source and microphone was set to approx. 3 cm. The sensor output voltage was amplified by a factor of 10.

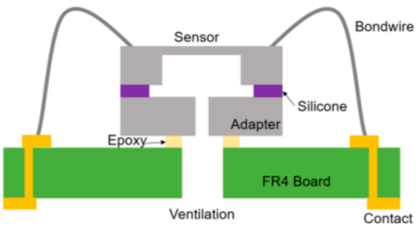

Fig. 2. Package with FR4-PCB with back chamber ventilation and silicon adapter chip

Measurement Results

The speaker was excited with a chirp signal with frequencies between 5-50 kHz. Due to a lack of DAQ-channels, firstly the reference microphone signal was recorded and secondly the device under test (DUT). To calculate the frequency response of the DUT, the values of the reference mic where divided by the known sensitivity of the ref mic and then converted into the frequency domain by Fast Fourier Transformation (FFT), giving the frequency dependent pressures at the DUT. Then the DUT voltage values where converted by FFT and then normalised by the before calculated pressure values. The resulting graphs are shown in Fig. 3-5. Four samples for each membrane size were tested with a vent hole (wv – with vent) and without a vent hole (nv – no vent).

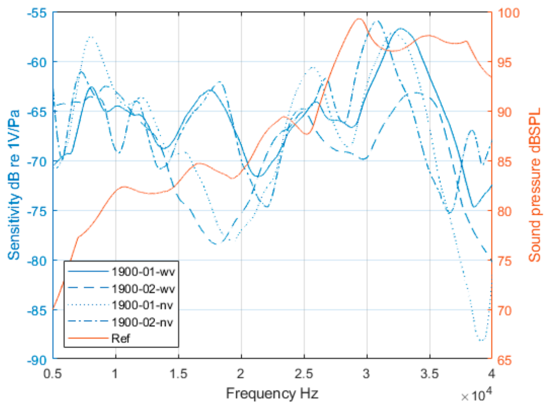

Fig. 3. Frequency response for DUTs 1900 µm

Outlook

Even though the presented measurement results show the functionality of the fabricated microphones, the tests need to be repeated with higher numbers of samples, to quantify the deviation of the frequency response for every type of sensor. The resulting trends can then be compared with the simulation results in [2] and new design adaptions can be formulated to fit the specifications.

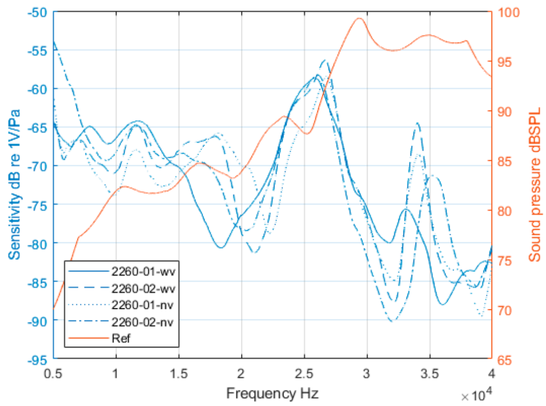

Fig. 4. Frequency response for DUTs 2260 µm

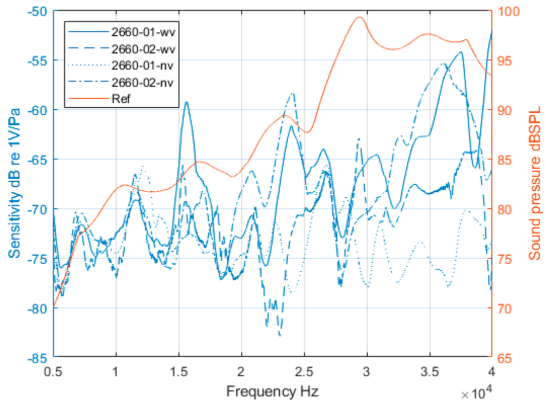

Fig. 5. Frequency response for DUTs 2660 µm

Outlook

In preparation for flight tests the samples will be investigated in the Bacchus test [3] at Airbus, where they can be exposed to the combination of flow and acoustic phenomenon. For the flight tests, the sensors will be embedded into flexible large area arrays [2].

Acknowledgement

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