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A Novel Barometric Pressure Sensor with a Capacitive Transducer and with Improved Mechanical Robustness in a Media Robust Packaging

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Summary:

This paper reports a novel barometric pressure sensor with a capacitive transducer for consumer application. The concept of the MEMS chip and the improvement in performance compared to the previous generation of pressure sensor are shown. Furthermore, bumpers were designed with the help of Finite Element Analysis (FEA) to improve the mechanical robustness of the transducer. Finally, by putting the MEMS chip into a media robust package further challenges raised that were investigated with FEA and solved with a novel packaging process.

Keywords: pressure sensor, capacitive transducer, bumpers, media robust, gel fill

Background, Motivation an Objective

Barometric pressure sensors are well known in automotive and consumer applications for a long time now. For such kind of sensors, there are two major MEMS technologies available on the market, either with piezoresistive or capacitive transducer [1]. Especially for applications that require low current consumption, low noise, and high accuracy, capacitive pressure sensors (CPS) are more suitable than piezoresistive pressure sensors (PZR) [2].

These sensors have robustness requirements to withstand certain overpressure loads or high mechanical shock. To fulfil these requirements, additional mechanical design measures might be necessary.

For certain use cases (e.g., in mobile phones or smart wearables), the sensor should withstand the water immersion of the device as well, thus a media robust sensor packaging is required. A common way to realize this is to cover the chip components of the sensor package with gel material. The gel material serves as chemical protection, on the other hand its incompressibility allows the transfer of the ambient pressure to the pressure sensitive-membrane. In addition, due to its very low stiffness (Young's modulus in kPa regime) the negative effect on the sensor performance is minimized.

Description of the New Method or System

In this paper a novel barometric pressure sensor is presented, containing a MEMS chip with capacitive transducer and some unique design and features in a media robust packaging (see Fig. 1). Those features are a stiffening structure within the membrane for improved sensitivity and an integrated reference capacitances for implementing an on-chip Wheatstone bridge (see Fig. 2).

The fulfillment of robustness requirements induced further design measures: bumpers were introduced on the non-stiffened region of the membrane to further reduce the mechanical stress in the structure during overpressure load.

The media robustness of the package was solved with an open, cylindrical lid and with filling the chip stack inside the lid with a gel material. However, it turned out that even the very soft gel material can cause a specific performance problem that needs to be solved to reach the performance requirements.

Results

The improved accuracy of the CPS is proven by a direct comparison to a previous generation PZR with a high-resolution measurement during a down and up stair climb (see Fig. 3). Each of the 15 steps, corresponding to a height difference of 15.5cm or ~2.1Pa per step, are clearly visible for the measurement with the CPS, whereas for the PZR the single steps are not resolved, only the overall height difference is captured.

FEA showed that during overpressure, the maximum mechanical stress occurs at the edges of the membrane. This mechanical stress can be effectively reduced in high pressure regime (>10bar) by introducing mechanical bumpers on the membrane (Fig. 4). With the help of FEA, a workflow was established to determine the optimal height, position and support of the bumpers and thus gain the highest reduction of the maximum mechanical stress. With the optimal bumper design, the mechanical stress can be reduced by ~30% at 10bar overpressure load and by ~60% at 50bar overpressure load (see Fig. 5).

The first media robust CPS samples showed a pressure accuracy problem that is caused by the earth gravitation. The sensor is so sensitive that by simply rotating the sensor by 180° (either the gravity pushes the membrane towards the enclosed cavity or the membrane is pulled away from it), the pressure signal changes by appr. 10Pa. FEA has shown that the gravity effect is considerable only if there is a high amount of gel on top of the membrane, because the effect is mainly affected by the mass of the gel. The final solution was the development of the so called "minimum gel fill" process, with which it is possible to cover all chip components in a way that the membrane is covered only with a few µm thick gel film (see Fig. 6). As the huge mass above the membrane is removed, the gravity effect becomes negligible, while the media protection is still kept.

Illustrations, Graphs, and Photographs

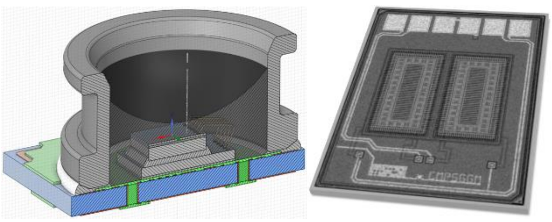

Fig. 1. Schematic cross-section of a barometric pressure sensor BMP585 from Bosch Sensortec with capacitive transducer concept, in a media robust packaging with standard gel fill (left); Optical image of the top of the MEMS chip (right)

Fig. 2. Schematic cross section of the sensing structure with stiffening structure and sense capacitance (A), reference capacitance (B) and membrane suspension (C).

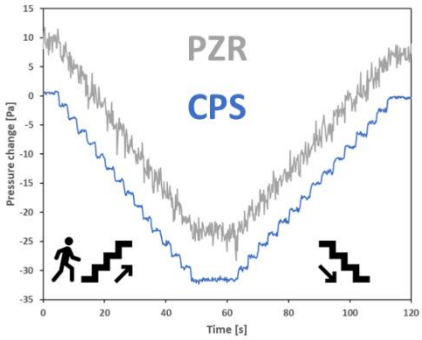

Fig. 3. High-resolution measurement during a down and up stair climb showing the improved accuracy of a capacitive pressure sensor (CPS) compared to a previous generation piezoresistive pressure sensor (PZR). The PZR signal is shifted by +10Pa for better readability.

Fig. 4. Schematic cross section of the sensing structure in a deflected state equipped with the mechanical bumpers (A). For better visibility, the deflected state is artificially scaled up.

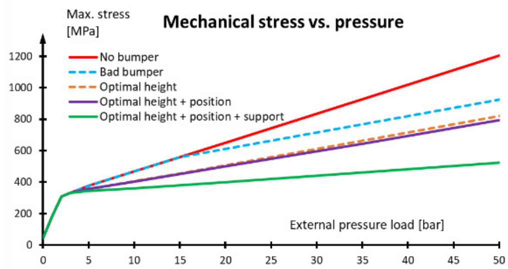

Fig. 5. Maximum mechanical stress over external pressure load for different bumper configurations.

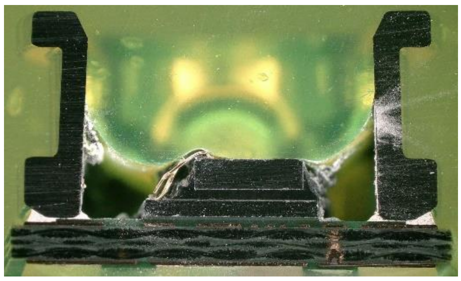

Fig. 6. Optical cross section image of the BMP585 pressure sensor with the new minimum gel fill process.

References

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