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Novel comb-type differential pressure sensor with silicon beams embedded in a silicone rubber membrane

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1. Introduction

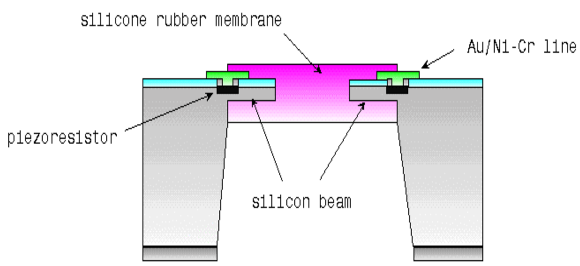
Solid-state pressure sensors have been developed for a wide range of applications, including those in automotive systems, biomedicine, and automated process control. In spite of recent progress, conventional differential pressure sensors suffer from relatively low sensitivity and low burst pressure [1]. In order to solve this problem, we have developed a novel comb-type differential pressure sensor with silicon beams embedded in a silicone rubber membrane. It is well known that silicone rubber exhibits a very low modulus, good compatibility with IC process, high elongation, and good sealing properties on rough surfaces [2]. Therefore, silicon beams embedded in a silicon rubber membrane can withstand higher burst pressure than conventional silicon diaphragms.

In many applications, pressure sensors are required to function reliably during exposure to harsh media. As a result, it is important to isolate media-sensitive elements of the device from harsh media. Commonly media isolation has been addressed at the packaging level using oil-filled, metal-can packages and polymeric protective coatings. It is well known that silicone rubber membrane is resistant to alcohol, positive photo-resist developer, KOH and buffered hydrofluoric acid for short periods of time. Therefore, silicone rubber membrane can properly operate during exposure to harsh environment.

2. Fabrication

Figure 1 shows the structure of the proposed differential pressure sensor.

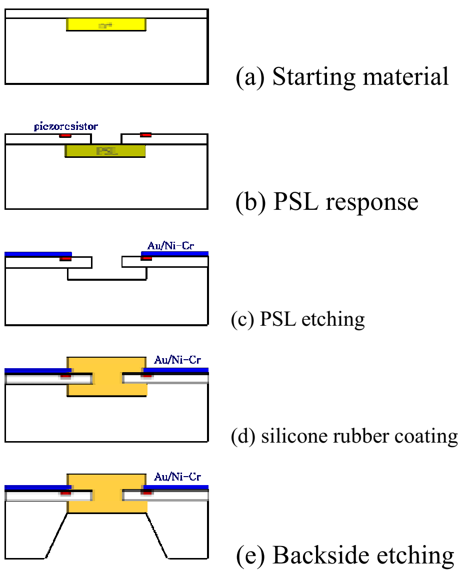
Fig. 1. Structure of the differential pressure sensor.



Proposed differential pressure sensor has been fabricated on the selectively diffused (100) oriented n/n+/n silicon substrates by unique silicon micro machining technique using porous silicon etching. Fabrication process of the differential pressure sensor is shown in Figure 2. Porous silicon layer is formed in the heavily doped n+ layer by anodic reaction in 10% aqueous solution of HF for 40 minutes by applying a constant voltage of 0.6 V.

This layer is etched away by subsequent etching process in 5% aqueous solution of NaOH for 20 minutes. Since anodic reaction does not proceed to the lightly doped n-type substrate, the reaction stops automatically after complete conversion of the n+ region to porous silicon. The resultant microstructure is thus well defined and uniform without a cusp or undercutting phenomenon. This indicates that the silicon beam thickness and the air-gap height of the microstructure can be well adjusted by controlling the thickness of the n-epitaxial layer and n+-diffused layer. After etching the porous silicon layer, a silicone rubber membrane is formed by coating. Backside of the wafer is etched in KOH to complete the fabrication process.

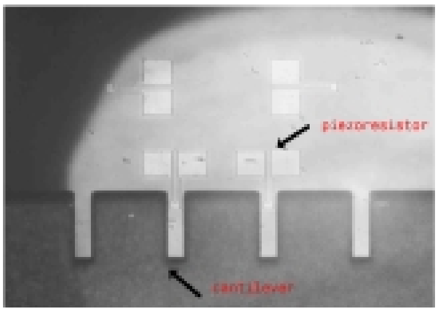
Fig. 2. Fabrication process of the differential pressure sensor.



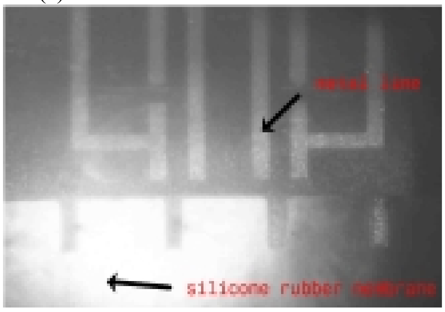
Fabricated sensors consist of a silicone rubber membrane, four silicon beams embedded in a silicone rubber membrane, four piezoresistors located on the beams, and four fixed resistors near the beams.

A photomicrograph of the fabricated sensor is shown in Figure 3. The photomicrographs of the fabricated differential pressure sensor without silicone rubber membrane and with it are shown in (a) and (b), respectively.

Fig. 3 Photomicrographs of the fabricated sensor.



(a) Without silicone rubber membrane

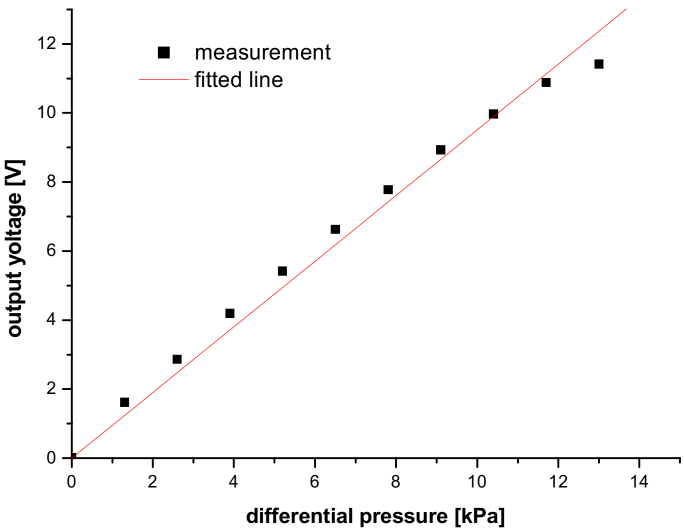


(b) With silicone rubber membrane

3. Results

The output response of the fabricated sensor have been measured with four outputs of the half-bridge, which is designed to symmetrically locate two piezoresistors located on the opposite sides of the beams. A typical output voltage versus applied pressure characteristics over 100mmHg of pressure difference is shown in Figure 4. The measured sensitivity is about 4.75 mV/kPa and the non-linearity is less than 1.8 % of FSO.

Fig. 4. Output characteristics of the fabricated differential pressure sensor.



4. Conclusion

A novel comb-type differential pressure sensor with silicon beams embedded in a silicone rubber membrane using selective porous silicon etching and dispensing mass loading methods has been designed, fabricated and characterized. It was demonstrated that porous silicon etching method has made it possible to precisely define dimensions of the beam and the air-gap of the microstructure by controlling the thickness of the n-epitaxial and n+ diffusion layers. The measured sensitivity is about 4.75 mV/kPa and the non-linearity is less than 1.8 % of FSO. Increasing the number of silicon beams, hence the number of piezoresistors and optimizing the thickness of the silicone rubber can further increase sensitivity of the sensor.

Acknowledgements

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References

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