Researchers develop MEMS accelerometer with higher sensitivity and improved noise reduction

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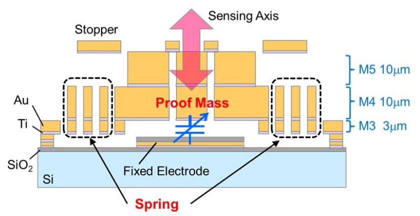


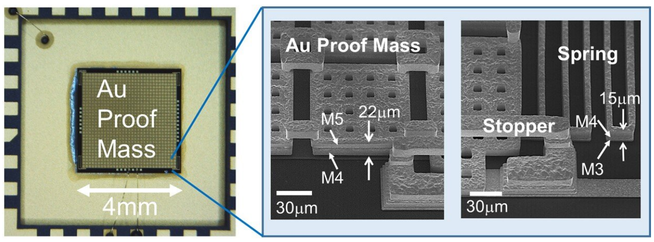
The illustration shows a schematic image of the proposed single-axis MEMS capacitive accelerometer. Input acceleration can be sensed by monitoring the capacitance change between the proof mass and the fixed electrode. The device is realized by the multiple layers made of electroplated gold. We utilize the third (M3) and fourth (M4) layers for the spring structure, and the M4 and fifth (M5) layers for the proof mass structure. Credit: Sensors and Materials, Daisuke Yamane

A significant increase in the demand of accelerometers is expected as the market for consumer electronics, such as smartphones, and social infrastructure monitoring applications are expanding. Such miniaturized and mass-producible accelerometers are commonly developed by silicon MEMS technology where the fabrication process is well established.

In the design of accelerometers, there is a trade-off between the size reduction and the noise reduction because the mechanical noise dominated by the Brownian noise is inversely proportional to the mass of the moving electrode called as proof mass. Moreover, capacitive accelerometers have sensitivity generally proportional to the accelerometer size, and thus there is also a trade-off between the size reduction and the sensitivity increase. Since high-resolution accelerometers require low noise and high sensitivity performances, it has been difficult for conventional silicon-based MEMS accelerometers to detect 1 ?G level input acceleration.

Low noise and high sensitivity MEMS accelerometer

The research group consisting of researchers from Tokyo Tech and NTT Advanced Technology Corporation has previously proposed a method to downscale the proof mass size of MEMS accelerometers to less than one-tenth by using gold material. In this work, as an extension of this achievement, they have employed multi-layer metal structures to the proof mass and spring components, and developed a low-noise, high-sensitivity MEMS accelerometer.

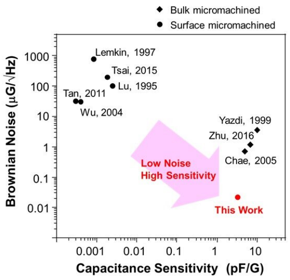


Left; The photo shows a developed high-sensitivity MEMS Accelerometer. The Au proof mass was fabricated on a silicon die. The accelerometer was implemented in a ceramic package and wire-bonded. Right; The SEM images show the close-up views of the Au proof mass and the spring structure. The Au proof-mass structure of 22-?m thickness was successfully developed by employing the M4 and M5 layers. The serpentine spring structure was made of the M3 and M4 layers. The serpentine springs and stoppers were placed at each corner of the proof mass. Credit: Sensors and Materials, Daisuke Yamane

As shown in Fig. 1, they reduced the Brownian noise, which is inversely proportional to the proof mass, by increasing the mass per area with the use of multiple layers of gold for the proof mass structure.

Furthermore, they utilized the whole area of the 4-mm-square chip by reducing the warpage of the proof mass, which enabled them to increase the capacitance sensitivity of the accelerometer. Figure 2 shows a chip photograph and scanning electron microscope images of the developed MEMS accelerometer.

The new accelerometer has sensitivity > 100 times over previous technology, and one-tenth less noise at the same size, as shown in Fig. 3. Accordingly, the researchers confirmed that the accelerometer can detect input acceleration as low as 1 ?G. The fabrication process entailed semiconductor microfabrication processes and electroplating, and thus it could be possible to implement the developed MEMS structures on an integrated circuit chip. Therefore, the proposed technology would be useful to increase the resolution of miniaturized accelerometers for general purpose use.



The graph shows a comparison of Brownian noise (BN) versus capacitance sensitivity. Thanks to the high density of gold, the BN achieved in this work was more than an order of magnitude lower than those of conventional devices when compared with the same sensitivity. Furthermore, our device was fabricated by surface micromachining that would useful for miniaturization. Credit: Sensors and Materials

The accelerometer could be applied to medical and healthcare technology, infrastructure monitoring, high-precision control of ultra-lightweight robots, mobile vehicle control, navigation systems in places where GPS cannot be used, and space environment measurement requiring ultra-low acceleration sensing.

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