# MEMS Accelerometers: the Theory of Operation, the Fabrication Methods and the Applications

## Abstract

Mems accelerometers are one of the simplest yet in addition most relevant microscale electromechanical frameworks. They wound up irreplaceable in the vehicle industry, pc, and sound video innovation. This report presents Mems technology as an exceedingly creating industry. Unique consideration is given to the capacitor accelerometers, how would they work, and their applications. The report closes with Mems fabrication.

## Introduction

An accelerometer is an electromechanical device that measures acceleration forces. These forces might be static or they could be dynamically brought about by moving or vibrating the accelerometer. Individuals tried to create something littler that could expand appropriateness and began looking in the field of microelectronics. They created MEMS (microelectromechanical systems) accelerometers.

The first micromachined accelerometer was structured in 1979 at Stanford University yet it took more than 15 years before such gadgets wound up acknowledged standard items for expansive volume applications. During the 1990s MEMS accelerometers reformed the car air-bag system industry. Recently, a similar sensor-core innovation has turned out to be accessible in completely incorporated full-included gadgets appropriate for mechanical applications.

Smaller-scale machined accelerometers are an exceedingly empowering innovation with enormous business potential. They give lower power minimized and vigorous detecting. Different sensors are regularly joined to give multi-axis detecting and progressively precise information.

## MEMS technology

Micro-Electro-Mechanical Systems or MEMS Technology is a precision device technology that integrates mechanical elements, sensors, actuators, and electronics on a common silicon substrate through microfabrication technology.

- Micro: Small size, micro-fabricated structures
- Electro: Electrical Signal/ Control
- Mechanical: Mechanical functionality
- Systems: Structures, Devices, Systems

## WHY MEMS?

1. MEMS allows the miniaturization of existing devices.
2. MEMS offers solutions which cannot be attained by micro-machined products, e.g., a capacitive pressure sensor capable of sensing the pressure of the order of 1 mTorr is not possible with the micromachined capacitive diaphragm.
3. MEMS allows the complex electromechanical systems to be manufactured using batch fabrication techniques, decreasing the cost and increasing the reliability.
4. It allows integrated systems, viz., sensors, actuators, circuits, etc. in a single package and offers advantages of reliability, performance, cost, ease of use, etc.

## MEMS accelerometers



When coupled with microelectronic circuits, MEMS sensors can be used to measure physical parameters such as acceleration. MEMS sensors measure frequencies down to 0 Hz (static or DC acceleration). Common manufactured types of MEMS accelerometers are variable capacitive and piezoresistive:

- Variable capacitive (VC) MEMS accelerometers are lower range, high sensitivity devices used for structural monitoring and constant acceleration measurements.
- Piezoresistive (PR) MEMS accelerometers are higher range, low sensitivity devices used in shock and blast applications.

### Example of one axis accelerometer:

Capacitive interfaces have several attractive features. In most micromachining technologies no or minimal additional processing is needed. Capacitors can operate both as sensors and actuators. They have excellent sensitivity and the transduction mechanism is intrinsically insensitive to temperature. Capacitive sensing is independent of the base material and relies on the variation of capacitance when the geometry of a capacitor is changing.

A typical MEMS accelerometer is composed of movable proof mass with plates that is attached through a mechanical suspension system to a reference frame, as shown in Figure. Movable plates and fixed outer plates represent capacitors. The deflection of the proof mass is measured using the capacitance difference. As one can see in Figure 3.1, every sensor has a lot of capacitor sets. All upper capacitors are wired parallel for an overall capacitance C1 and likewise all lower ones for overall capacitance C2, otherwise, capacitance difference would be negligible to detect. One can picture to himself this whole system as a simple voltage divider whose output goes forward through a buffer and demodulator. First of all, we are interested in voltage output Vx, which is actually the voltage of the proof mass. It holds true that:

$$V_x=V_o (C2-C1)/(C2+C1)=x/d\ V_o$$

The mass of the proof mass mentioned above is approximately 0:1?g, the smallest detectable capacitance change is ? 20aF, and gaps between capacitor plates are approximately 1.3?m.

## The MEMS materials

The choice of a good material for MEMS application is no more based like in microelectronics on carrier mobility, but on more mechanical aspects: small or controllable internal stress, low processing temperature, compatibility with other materials, possibility to obtain thick layer, patterning possibilities.

### Silicon and its compounds:

It is an excellent mechanical material. Silicon is almost as strong but lighter than steel, has large critical stress, and has no elasticity limit at room temperature as it is a perfect crystal ensuring that it will recover from large strain. Unfortunately, it is brittle and this may pose a problem in handling wafers, but it is rarely a source of failure for MEMS components. But silicon and its derivative are not the only choices for MEMS, many other materials are also used because they possess some unique properties:

- Quartz crystal (strong piezoelectric effect).
- Glass (forms tight bond with silicon, bio-compatibility).
- Polymers (biodegradability and bioabsorbability, versatility, thermoplastic property).
- Metals (conductivity, ability to be grown in thin films).

### Bulk micromachining:

Bulk micromachining refers to the formation of microstructures by the removal of materials from bulk substrates. We said that bulk substrates in wafer form can be silicon, glass, quartz, crystalline Ge, SiC, GaAs, GaP or InP. The methods commonly used to remove excess material are wet and dry etching, allowing varying degrees of control on the profile of the final structure.

### Surface micromachining

Unlike bulk micromachining in which microstructures are formed by etching into the bulk substrate, surface micromachining builds up structures by adding materials, layer by layer, on the surface of the substrate. The thin film layers are typically 15 m thick, some acting as a structural layers and others as sacrificial layers. Dry etching is usually used to define the shape of the structure and supporting layers, and a final wet etching step releases them from the substrate by removing the supporting sacrificial layer. A typical surface micromachining process sequence to build a microbridge is shown in Figure.

### DRIE micromachining

Deep reactive ion etching (DRIE) micromachining shares feature both from the surface and bulk micromachining. DRIE uses high-density plasma to produce long vertical walls, by applying anisotropic etching through a two-phase sequence composed of etching and protective layer deposition. With DRIE we can build much more complex structures. Figure 4.7 shows a simplified process on silicon-on-oxide (SOI) wafer using (DRIE), a special MEMS dry etch technique allowing large etching depth with very vertical sidewalls. This simple, yet powerful, the technique needs only one mask to obtain working devices, and it is understandably used in commercial products.

## Applications

- Personal electronic devices such as media players, gaming devices, and smartphones.
- Smartphones are incorporating accelerometers for step counters, user interface control, and switching between portrait and landscape modes.
- As a tilt sensor for tagging the orientation to photos taken with the built-in camera.
- In Cameras: image stabilization, and anti-blur capturing.
- In laptops: to protect hard drives from damage. If you accidentally drop the laptop, the accelerometer detects the sudden freefall and switches the hard drive off so the heads don’t crash on the platters.
- High g accelerometers are the industry standard way of detecting car crashes and deploying airbags at just the right time. They are used to detect the rapid negative acceleration of the vehicle to determine when a collision has occurred.
- controlling and monitoring military and aerospace systems. Smart weapon systems (direct and indirect fire; aviation-launched and ship-launched missiles, rockets, projectiles, and sub-munitions) are among these applications.
- Some MEMS sensors have already been used in satellites.

## Summary

Although some products like pressure sensors have been produced for 30 years, the MEMS industry in many aspects is still a young industry. MEMS will undoubtedly invade more and more consumer products. The size of MEMS is getting smaller, and frequency response and sense range are getting wider. MEMS are more and more reliable and their sensitivity is better every day. Prices of MEMS accelerometers and other MEMS devices aren't excessive, but they still have to drop a lot if we want to expand massive consumption. Standardization of production, testing, and packaging MEMS would certainly do a big part at it. The relatively long and expensive development cycle for a MEMS component is a hurdle that needs to be lowered and also less expensive micro-fabrication method than photolithography has to be pursued. We can be sure that the future for MEMS is bright. At least because, as R. Feynman stated boldly in his famous 1959 talk, which inspired some of the MEMS pioneers, because, indeed, 'There's plenty of room at the bottom!'.

## References

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