A Review Paper on Recent Developments in MEMS Sensors and its Applications in Automobiles

[1]Kaustubh S Pawar, [2]Manoj P Bauskar

[1]Student, [2]Assistant Professor
Department of Mechanical Engineering,
All India Shri Shivaji Memorial Society's College of Engineering, Pune-01, India

***Abstract*: MEMS (Micro-electromechanical systems) is an advanced technology that finds its application in several fields i.e., automotive electronics, medical equipment, hard disk drives, computer peripherals, wireless devices. This paper focuses on the application of MEMS devices exclusively in the automotive field. Pressure sensors have maximum demand in cars. After pressure sensors, the second largest demand is of accelerometer sensor. Other sensors such as Acoustic, Moisture, and Piezoresistive sensors are also in demand. In recent years, MEMS technology with a broad variety of MEMS sensors has been used widely in the automotive industry so much that at least 30 sensor nodes of a modern vehicle with 100 sensor nodes are MEMS and the automotive industry is the second largest market of MEMS technology.**

***Keywords*: MEMS, Pressure Sensors, Automobile Applications**

1. INTRODUCTION

MEMS technology is finding its importance in various fields of application. The field includes automobiles, health science, engineering structures, electrical, physics, electronics and many more. MEMS sensors have been embraced by the automotive industry in its quest to improve performance, reduce cost, and enhance the reliability of the family sedan which are critical issues in developing countries. In fact, hundreds of millions of MEMS sensors have been used in automobiles over the past decade. Many of these sensors (e.g., MEMS pressure sensors) simply replace older technologies with cheaper, more reliable devices. The attractive features of MEMS devices that have fascinated several researchers towards it includes its high sensitivity, high flexibility, high reliability, its capacity to integrate on a single chip due to its miniature size, parallelism and many more. This paper highlights the major areas of MEMS sensor applications in a car. Talking about MEMS components, it mainly comprises of four major components: microactuator, microsensors, microstructures, and microelectronics.

1.1 MEMS FABRICATION

Most of the MEMS fabrication methods are adopted from standard IC technology. The most common techniques are: bulk micromachining and surface micromachining.

1) Bulk Micromachining

In bulk micromachining, a 3D micro-mechanical structure is built directly on the silicon wafer by selectively removing portions of the substrate. The exposed area on the substrate is subjected to further chemical etching.

2) Anisotropic etching

Utilize the crystallographic structure of the silicon lattice.

3) Isotropic etching

In this the silicon substrate is attack in all directions with equal rate.

4) Surface Micromachining

Surface micromachining is based on the deposition of layers on the substrate, and on the subsequent definition of the micro-mechanical structure by means of photolithographic techniques.

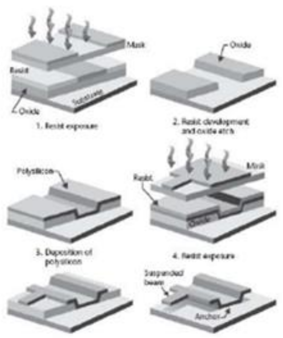

Figure 1: MEMS Fabrication

1.2 MATERIALS FOR MEMS
There are many materials that used in MEMS manufacturing, **Silicon-Compatible Material**, such as: Silicon, Silicon Oxide and Nitride, Thin Metal Films, Polymers. **Other Materials and Substrates**: Glass and Fused Quartz Substrates, Silicon Carbide and Diamond Gallium Arsenide and other Group III-V Compound. Semiconductors, Polymers, Shape-Memory Alloys. But the most common material used in MEMS is Silicon.

2. AUTOMOTIVE: THE FIRST HIGH VOLUME APPLICATION
Early airbags required the installation of several bulky accelerometers made of discrete components mounted in the front of the car, with separate electronics near the airbag. Today, because of MEMS, the accelerometer and electronics are integrated on a single chip. The small size provides a quicker response to rapid deceleration. The sensitivity of MEMS devices is also leading to improvements where size and weight of passengers will be calculated so the airbag response will be appropriate for each passenger.

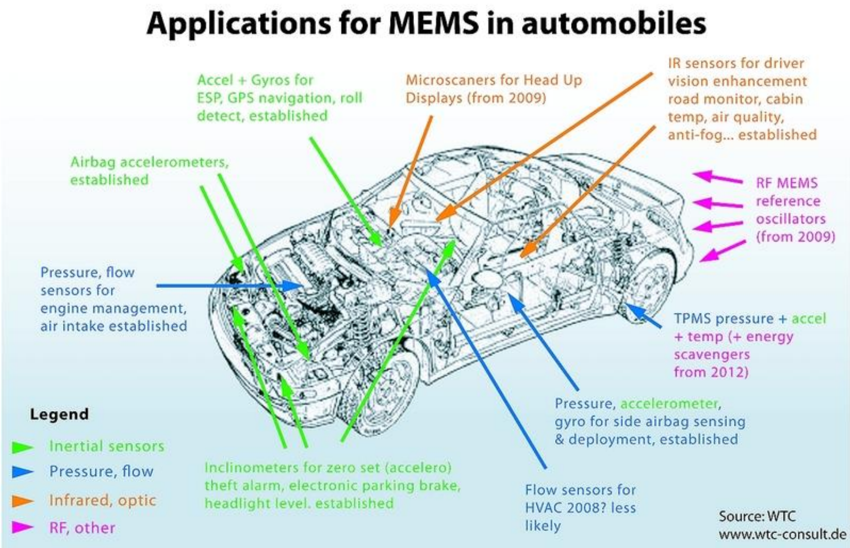

Figure 2: MEMS in Automotive Applications

2.1 FUEL INJECTOR PRESSURE SENSOR
The MPFI (multi point fuel injection) system is used, assuring proper air fuel ratio to the engine by electrically injecting fuel in accordance with various driving conditions. MPFI system injects fuel into individual cylinders, based on commands from the 'on board engine management system computer' – popularly known as the Engine Control Unit/ECU. These techniques result not only in better 'power balance' amongst the cylinders but also in higher output from each one of them, along with faster throttle response. The electronic fuel injection system supplies the combustion chambers with air/fuel mixture of optimized ratio under widely varying driving conditions.

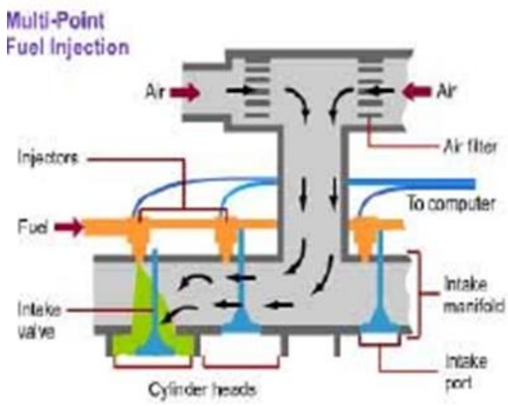

Figure 3: Fuel Injector Pressure Sensor

Sensors used are:
- Manifold absolute pressure (MAP) sensor, Throttle position sensor, Intake air temperature sensor
- Engine coolant temperature sensor, Oxygen sensor, Vehicle speed sensor, Camshaft position sensor
- Crank shaft position sensor

2.2 CRASH SENSING FOR AIRBAG CONTROL
Crash sensing for air bag control represents the largest automotive use of inertial MEMS sensors. In this application, an accelerometer continuously measures the acceleration of the car. When this parameter goes beyond a predetermined threshold, a microcontroller computes the integral of the acceleration (i.e., the area under the curve) to determine if a large net change in velocity has occurred. If it has, the air bag is fired.

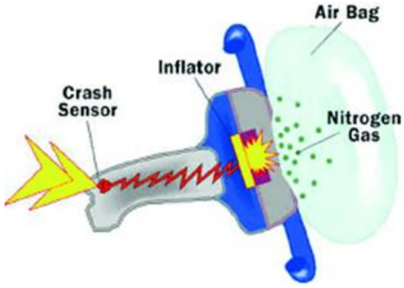

Figure 4: MEMS crash sensor

2.3 VEHICLE DYNAMIC CONTROL SYSTEM
Vehicle dynamic control (VDC) systems help the driver regain control of the automobile when it starts to skid. If the VDC works properly, the driver may not even be aware that the system intervened. A VDC system consists of a gyroscope, a low-g accelerometer, and wheel-speed sensors at each wheel (the wheel-speed sensors may also be used by the ABS). Wheel speed is measured, and the predicted yaw (or turn) rate of the car is compared with that measured by the gyroscope. A low-g accelerometer is also used to determine if the car is sliding laterally. If the measured yaw rate differs from the computed yaw rate, or if lateral sliding is detected, single-wheel braking or torque reduction can be used to make the car get back in line.

2.4 ROLLOVER DETECTION SYSTEM
Few vehicles have rollover detection systems, but automakers are rapidly adopting this feature. This is particularly true for vans, pickup trucks, and sport utility vehicles, which are more likely to roll over because of their higher center of gravity. These systems read the roll angle and roll rate of the vehicle to determine if it is tipping over. If it is, the system fires the side curtain air bags to protect the occupants. Rollover detection systems use a gyroscope to read the roll rate. The roll rate is integrated to determine the roll angle of the vehicle, but roll rate data alone are not enough to predict if a vehicle is (or will be) rolling over. An accelerometer reading vertical acceleration (Z axis) is also required because large roll angles can be encountered in banked curves with no possibility of rollover.

2.5 VEHICLE NAVIGATION SYSTEM
Vehicle navigation systems are rapidly becoming a standard feature in luxury automobiles. In Japan, more than half the cars sold in 2001 were equipped with navigation systems. A global positioning system (GPS) is a fundamental part of a navigation system, but GPS information alone is insufficient for navigation. The GPS can tell you where you are (position and altitude), but not what direction you are facing. Magnetometers (electronic compasses) are not reliable because they're confused by large ferrous metal objects close by (e.g., a truck full of scrap metal in the next lane). Navigation systems rely on compass and GPS information when the system is first started. The direction of travel is matched up with map data to give the system more certainty regarding direction. Once initial direction is established, gyroscope information is used to determine when and how much the car has turned, until directional data can be verified by map matching. In urban settings, it's not unusual for the GPS signal to be obscured by tall buildings or tunnels for short periods. At these times, the navigation system relies on the gyroscope for heading information and a low-g accelerometer for position information. The acceleration signal is integrated twice to derive position (this technique is called dead reckoning).

CONCLUSION
In this paper, the newest and most important applications of the MEMS technology in the automotive industry have been introduced. It has been shown that many of the previous sensors can be simply replaced by the more cost-effective, safer, and smaller MEMS sensors. Besides, most forecasts suggest that their application in the vehicles will continue to grow to address vehicle safety requirements as well as government mandates. Furthermore, due to the considerable advantages of such sensors in terms of technical and economic aspects, car engineers continually discover new applications for them so that the safety and efficiency of the vehicles can be enhanced. Now, the manufacturers usually use the MEMS sensors in the vehicle safety parameters.

Today, manufacturers primarily use inertial MEMS sensors to implement safety features (e.g., air bag control), but performance and convenience applications are quickly becoming a major market.

The potential exists for MEMS to establish a second technological revolution of miniaturization that may create an industry that exceeds the IC industry in both size and impact on society.

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