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### REVIEW PAPER ON MEMS DOMAIN

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#### ABSTRACT

MEMS is a new manufacturing technology, a new way of making complex electromechanical systems using batch fabrication techniques similar to the way integrated circuits are made and making these electromechanical elements along with electronics. Since MEMS devices are manufactured using batch fabrication techniques, similar to ICs, unprecedented levels of functionality, reliability, and sophistication can be placed on a small silicon chip at a relatively low cost. MEMS technology is enabling new discoveries in science and engineering such as the polymerize chain reaction (PCR) Microsystems for DNA amplification and identification, the micro machined scanning tunneling microscopes (STMS), biochips for detection of hazardous and selection. In the industrial sector, MEMS devices are emerging as product performance differentiates in numerous markets with a projected market growth of over 50% per year. As a breakthrough technology, allowing unparalleled synergy between hitherto unrelated fields of endeavour such as biology and microelectronics, many new MEMS applications will emerge, expanding beyond that which is currently identified or known.

**KEYWORDS:** MEMS, PCR, DNA, STMS, biochips.

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#### INTRODUCTION

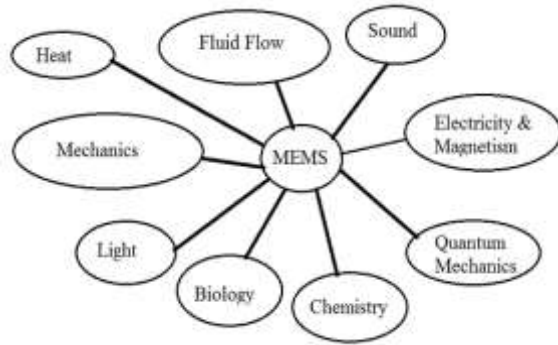
Micro-Electro-Mechanical Systems, or MEMS, is a technology that in its most general form can be defined as miniaturized mechanical and electro-mechanical elements (i.e., devices and structures) that are made using the techniques of micro fabrication. The critical physical dimensions of MEMS devices can vary from well below one micron on the lower end of the dimensional spectrum, all the way to several millimeters. Likewise, the types of MEMS devices can vary from relatively simple structures having no moving elements, to extremely complex electromechanical systems with multiple moving elements under the control of integrated microelectronics. In Microsystems, microelectronic integrated circuits (ICs) can be thought of as the “brains” of system and MEMS augment this decision-making capability with “eyes” and “arms”, to allow Microsystems to sense and control the environment. The one main criterion of MEMS is that there are at least some elements having some sort of mechanical functionality whether or not these elements can move. The sensor gathers the information from the environment through measuring mechanical, thermal, biological, chemical, optical, and magnetic phenomena. While the electronics process the information derived from the sensors and

through some decision making capability direct the actuators to response by moving, positioning, regulating, pumping, and filtering, thereby, are controlling the environment for some desired outcome or purpose. The term used to define MEMS varies in different parts of the world. In the United States they are predominantly called MEMS, while in some other parts of the world they are called “Microsystems Technology” or “micromachined devices”.

The microsensors are the sensors which have dimensions comparable with the  $10^{-6}$  meters, Similarly microactuators are the actuators lies dimensions in the micron region. Microelectronics is similar to the VLSI fabricated Integrated Circuits thus forming Microstructures.

#### VARIOUS DOMAINS OF MEMS

As a breakthrough technology, allowing unparalleled synergy between hitherto unrelated fields of endeavour such as biology and microelectronics, many new MEMS applications will emerge, expanding beyond that which is currently identified or known.



### *Different Domains of MEMS Applications*

Interestingly, even though the performance of MEMS devices and systems is expected to be superior to macro scale components and systems, the price is predicted to be much lower.

### **MEMS Fabrication Techniques**

There are three broad types of MEMS Fabrication as shown below:

#### ***Bulk micromachining***

Bulk micromachining is the oldest paradigm of silicon based MEMS. The whole thickness of a silicon wafer is used for building the micro-mechanical structures. Silicon is machined using various etching processes. Anodic bonding of glass plates or additional silicon wafers is used for adding features in the third dimension and for hermetic encapsulation. Bulk micromachining has been essential in enabling high performance pressure sensors and accelerometers that have changed the shape of the sensor industry in the 80's and 90's.

#### ***Surface micromachining***

Surface micromachining uses layers deposited on the surface of a substrate as the structural materials, rather than using the substrate itself. Surface micromachining was created in the late 1980s to render micromachining of silicon more compatible with planar integrated circuit technology, with the goal of combining MEMS and integrated circuits on the same silicon wafer. The original surface micromachining concept was based on thin polycrystalline silicon layers patterned as movable mechanical structures and released by sacrificial etching of the underlying oxide layer. Interdigital comb electrodes were used to produce in-plane forces and to detect in-plane movement capacitively. This MEMS paradigm has enabled the manufacturing of low cost accelerometers for e.g. automotive air-bag systems and other applications where low performance and/or high g-ranges are sufficient. Analog Devices have pioneered the industrialization of surface micromachining and have realized the co-integration of MEMS and integrated circuits.

### ***High aspect ratio (HAR) silicon micromachining***

Both bulk and surface silicon micromachining are used in the industrial production of sensors, ink-jet nozzles, and other devices. But in many cases the distinction between these two has diminished. A new etching technology, deep reactive-ion etching, has made it possible to combine good performance typical of bulk micromachining with comb structures and in-plane operation typical of surface micromachining. While it is common in surface micromachining to have structural layer thickness in the range of 2  $\mu\text{m}$ , in HAR silicon micromachining the thickness can be from 10 to 100  $\mu\text{m}$ . The materials commonly used in HAR silicon micromachining are thick polycrystalline silicon, known as epi-poly, and bonded silicon-on-insulator (SOI) wafers although processes for bulk silicon wafer also have been created (SCREAM). Bonding a second wafer by glass frit bonding, anodic bonding or alloy bonding is used to protect the MEMS structures. Integrated circuits are typically not combined with HAR silicon micromachining.

Companies with strong MEMS programs come in many sizes. The larger firms specialize in manufacturing high volume inexpensive components or packaged solutions for end markets such as automobiles, biomedical, and electronics. The successful small firms provide value in innovative solutions and absorb the expense of custom fabrication with high sales margins. In addition, both large and small companies work in R&D to explore MEMS technology.

### **Gas Sensors**

Gas sensors are used for sensing a particular Gas in the environment. Some compounds such as tin oxide, tungsten oxide or indium oxide, which are operated at elevated temperatures of 200-400.C. At those high temperatures these oxide shows considerable resistances changes upon exposures to a multitude of inorganic gases and volatile organics [10].

Gas sensors are not the invention of today's world but it is using by many years before too. In different words we can say that I gas detector is a device which detects the presence of various gases within an area, usually as part of a safety system. The type of equipment is used to detect a gas leak and interface with a control system so a process can be automatically shut down. A gas detector can also sound an alarm to operators in the area where the leak is occurring, giving them the opportunity to leave the area. This type of device is important because there are many gases that can be harmful to organic life, such as humans or animals. So we can

say that gas sensors are used generally for safety purposes.

While many of the older, standard gas detector units were originally fabricated to detect one gas, modern multifunctional or multi-gas devices are capable of detecting several gases at once. Some detectors may be utilized as individual units to monitor small workspace areas, or units can be combined or linked together to create a protection system.

As detectors measure a specified gas concentration, the sensor response serves as the reference point or scale. When the sensor response surpasses a certain pre-set level, an alarm will activate to warn the user. There are various types of detectors available and the majority serves the same function: to monitor and warn of a dangerous gas level. However, when considering what type of detector to install, it is helpful to consider the different sensor technologies. Gas detectors are categorized by the type of gas they detect: combustible or toxic. Within this broad categorization, they are further defined by the technology they use: catalytic and infrared sensors detect combustible gases and electrochemical and metal oxide semiconductor technologies generally detect toxic gases.

### Microheaters

A microheater is a device with area in microns and generates very high temperatures (>200°C) at considerable low input voltage (<5V) by the effect of joule heating. Microheaters have been extensively investigated and researched because of their applications in gas sensors, flow rate sensors, Humidity sensors, Microfluidics and other Microsystems. Micro heaters are an essential part in chemo-resistive gas sensors. Semiconducting Metal oxides like SnO<sub>2</sub>, ZnO and TiO<sub>2</sub> have long been used for detecting poisonous (CO) and inflammable gases (CH<sub>4</sub>) by their change in conductivity. In a semiconductor gas sensor a micro-heater is used as a hot plate which controls the temperature of the sensing layer. The semiconductor gas sensor utilizes semiconductor properties of surface adsorption to detect changes in resistance as a function of varying concentrations of different gases [20].

Optimization of a gas sensor's performance requires suitable heater geometry in order to ensure a uniform temperature distribution. The required and desired function of the microheater is to minimize the standard deviation of the temperature across an area over which the gas sensing layer is going to be deposited. The microheater works based on Joule heating, in which the electrical current is passed through a resistive heating element and converted into heat [21]. The heating element is made of an electrically conductive material mainly platinum and

is fabricated into a mostly spiral patterns to achieve the resistance required by the power supply applied to the heater in a small area.

### Micro Hotplate

During the last years, so called 'Micro Hotplate' has been developed in order to reduce the thermal mass of metal oxide gas sensor. Micro Hotplate consists of a thermally isolated stage with a heater structure, a temperature sensor and a set of contact electrodes for the sensitive layers. By using such Microstructures high operation sensors can be reached at comparably low power consumption (<100mW).

### Historical Overview

#### *P. Bhattacharyya et-al, 2005*

They concluded that use of nanocrystalline metal oxides in place of polycrystalline metal oxide lead to large increase of free surface energy which in turn leads to lower adsorption isotherm and large surface concentration and hence enhances reaction rate even at a much lower temperature.

#### *P-Fuejes et-al, 2007*

Their work was intended to determine the thermal properties of Silicon Nitride and Diamond layers applied in thermal sensor structure by analyzing thermal response of a multilayer micro heater structure.

#### *Ming-Tsun Ke et-al, 2009*

Their model consisted of a quartz substrate, a thin film WO<sub>3</sub> sensing layer, an integrated Pt micro heater and Pt interdigitated electrodes (IDEs). When benzene is present in the atmosphere, oxidation occurs on the heated WO<sub>3</sub> sensing layer. It is found that the sensitivity of the gas sensor is optimized at a working temperature of 300°C.

*Mario Alfredo Reyes Barranca et al, 2010* demonstrated that a standard CMOS technology can be compatible with micromachining processes used for MEMS structures, using a post-processing etching step for micromachining a membrane that contains the micro-heater.

*Velmathi G et-al, 2010* found that by analyzing the different geometries and their simulation results we can compare the various designs on the basis of the following specifications:

- The required temperature range
- Maximum and average sensor temperature
- Power consumption
- Required heater resistance for the given power consumption.

#### *Vineet Bansal et.al, 2011*

They found that a spiral micro heater is optimized for low power consumption applications, which have

uniform temperature distribution properties at low power consumption.

**Woo-Jin Hwang et al, 2011** found that the uniform area of high temperature for the power compensated micro-heater was around 2.5 times larger than that of the uncompensated micro-heater. In this case, the area where the temperature was more than 90% of the maximum temperature became more than 80% of the total heating area. This indicates that the heating area was substantially increased and shows that the micro-heater with the compensation design is suitable for use in a temperature-dependent semiconductor gas sensor.

**Xian Yi et.al, 2011**

They were fabricated a micro hotplate with Silicon on Insulator (SOI) as the substrate and metal Gold (Au) as the heating electrode material, which shows low thermal conductivity coefficient, good electrical insulation, low power consumption and excellent resistance to high temperature and low pressure.

**A.A. Vasiliev et-al, 2012**

MEMS platform based on ZrO<sub>2</sub> and alumina membranes were applied, which permits a decrease in MEMS power consumption at 450°C down to ~75mW at continuous heating and down to ~1mW at pulse heating of gas sensors.

**Monika et-al, 2013**

They concluded that as the thickness of the heating element is increased from 0.25µm to 2µm, the power consumption of the micro hotplate increases from 4.mW to 37mW at 0.8V with a square cavity in Silicon membrane. So, the power consumption depends on the geometry and type of material used for heating purpose.

**Santanu Maity et-al, 2013** concluded that Micro electro mechanical based gas sensor is well established technique for getting low power consumption. Here the MEMS structure is used and ZnO sensing material is also fabricated. The characteristics of ZnO nanoparticle sensors under various operation temperatures were examined. The optimized operating temperature was 120 °C with the proposed ZnO nanowire designed.

**Seung Eon Moon et-al, 2013**

For real time monitoring applications, a subsystem was developed using a gas sensor module, a Bluetooth module and a personal digital assistant (PDA) phone. The gas sensor module consisted of a NO<sub>2</sub> or CO gas sensor and signal processing chips. The responses of a semiconductor type MEMS gas sensor for gases NO<sub>2</sub> & CO were about 2.9 & 0.15 for 1ppm NO<sub>2</sub> and 10ppm CO with 15mW power consumption.

**Ying Li et.al, 2014** concluded that CMOS compatible micro hotplate gas sensor employing tungsten resistive heaters have low power consumption (about 19mW) and fast thermal response time (about 8ms) for heating up to 300°C for 336 hours.

## CONCLUSION

MEMS is believed to become a hallmark 21<sup>st</sup> - century manufacturing technology with numerous and diverse applications having a dramatic impact on everything from aerospace technology to biotechnology. The MEMS technology now being forged in R&D labs will generate new technological capabilities for society, tremendous economic growth through countless commercial opportunities, many of new products, and thousands of high-paying, high quality jobs. As breakthrough technology allowing unparalleled synergy between hitherto unrelated fields of endeavor such as biology and microelectronics, MEMS is forecasted to have a commercial and defense market growth similar to its parent IC technology.

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