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MEMS Design Techniques and Performance Estimation in Connected Cars

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Abstract*: In order to design the complex structure, devices , systems of electronic products under the level micrometers the micro-electromechanical and micromachining system (MEMS) are mostly preferred. Micro machining techniques are initially lent directly from electronic integrated circuit (IC) industry. But now there were many techniques proposed with wide variety of transduction directly. Ample variety of MEMS transduction process can be used to convert real-world signal from one to another form. The process of conversion can be can be enabled by combining different sensors, actuators and Microsystems. Due to the process of partial consistency and a growing technology, the complex designs of sophisticated MEMS are produced. The combination of integrated circuits with MEMS can improve performance, but at the rate of development cost, complexity and time. With the fact & fast development and growth in the area of automotive electronics, IoT, cloud computing, artificial intelligence and machine learning technologies prompted us to have higher potential market to make the successful products which can impact the social and economic growth. In addition to this, MEMS are well appropriate for automation, medical electronics, and agriculture and space exploration. Thus will play an important and major role in future mission both in private and public sectors. The major problem in India and other developing countries are safety and security. This paper describes the optimal solution & design methodology to control the user end application using MEMS senso., where the controlling of the machineries can be done by MEMS sensor to control communicate via wireless communication

***Keywords:* MEMS,HARM, ASIC, CVD, Micromachining, Macro machining, IIoT, micro fluidics,ECU.**

I. INTRODUCTION

The multidisciplinary nature of MEMS depends on design engineering and manufacturing expertise from a wide and diverse range of technical areas including IC fabrication, electrical engineering, mechanical engineering, materials science, chemical technology& engineering, fluid & engineering optics, instrumentation and packaging.

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Complexity & application of MEMS device also has a widespread range of market and range from consumer electronics goods, defense applications, medical, automotive, communication to internet application. The present trend of MEMS market includes some of the examples of MEMS devices include microphones, optical switches, projection display chips, accelerometers for airbag sensors and tire pressure sensors, some of the components like lab on chip(LOC), bio-sensors and other products. The report includes the field of MEMS into six main sections. The First sections deal with the deals with the part of MEMS.
Second section describes the definition, current trends and potential applications. The third part of the paper holds the concepts of market strategy with the issues concerning miniaturization. The Fourth section deals with the applications, markets, industrialization. The fifth section gives fabrication methods of MEMS technology. The final section deals with complexity and product life cycle, synopsis of MEMS products. some important trends in MEMS and conclusion and future scope.

II. DEFINITIONS AND DESIGN PROCESS POTENTIAL APPLICATIONS

MEMS is an integral and interdisciplinary technological model and fabrication is made by micrometer technology with micro sensors and actuators. As there is a rapid growth in the consumer electronics and automotive industry, the development process must undergo the more précised manner by weeding the design process and faster optimization to satisfy the customer needs. MEMS device design is basically an repetitive process for assessment. At first the design is kept under simulation mechanism and check for the correctness of the design and resubmitted for simulation until the design gets fit into the demand. A schematic representation of the MEMS design flow path is shown in Figure 1.

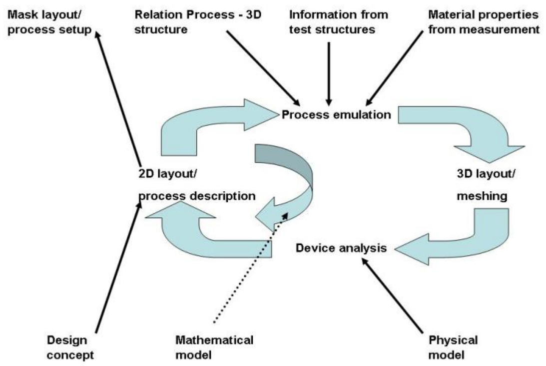

Fig 1: Schematic representation of MEMS Process

The structure of MEMS is designed and fabricated by micro-mechanical components ,which are are constructed by manipulations of silicon and other materials by micromachining process such as bulk and surface micromachining called high-aspect-ratio micromachining (HARM)[1].Therefore this process selectively removes SI layer or add structural layers to form the electromechanical properties from electrical and mechanical layers.

Therefore the integrated circuits are designed to exploit the electrical, mechanical, optical, physical and biological properties of silicon. Thus MEMS takes advantage of these material properties to create the new dimensions in this technology era. On the whole MEMS devices are tiny in nature and their sizing is microscopic. Some examples like pistons, gears, Pumps, and valves motors, steam engines have been designed and fabricated by MEMS technology [7]. MEMS is mainly manufacturing & process technology. A paradigm to design and create the complex integrated circuits, devices and systems using batch fabrication process similar to the technologies that were used in manufacturing process or standard technologies extended to the nanometer. MEMS has several advantages. The First is the interdisciplinary in nature & technology and diversity of applications. Second is fabrication techniques, that were used in MEMS with its components and devices to be manufactured to increase the performance, reliability by reducing physical size[9], weight, volume and cost[2]. Thirdly, it provides the basis for the manufacturing the tiny products that cannot be made by traditional methods or process. These factors make MEMS as reliable and efficient technology as integrated circuit microchips for the next generations [3]. However, above points makes the MEMS devices are different. The Main tendency of MEMS products to be application specific (ASIC), giving rise to wide products. But the limitations with the MEMS devices are no standard building block like transistor in MEMS technology and designing products are always less than the ICs. This leads to a more diversity in engineering, technology & development. Therefore it's been bit difficult to maintain mems technology compared to IC technology.

III. CLSSIFICATION: MEMS MODELS

In this section we describe some of the key terminology and mems classification associated with the MEMS technology. Basically mem is a process technology that is used to create tiny mechanical devices or systems; as a result it leads to MST. There are some overlaps in IC technology its applications. Therefore it is difficult to classify MEMS devices in view of sensing domain. Micro fluidics refers to the size of 500 µm or smaller[4,9]. Specifically biochips, which are made from glass, silicon and polymer facilitates reaction with DNA. How ever these devices are used for clinical and point of care diagnostics, drug development, scientific research, food and environmental monitoring ,agriculture. Biochips are divided into micro fluidics chips & microarray chips. These micro fluidics chips are also called as Lab-on-Chip[5], which is a micro-analytical device, consists of valves, pumps, micro channels and reactors to direct the test samples and other reagents. These chips includes an array of biosensors and read-out devices[6]. Some of the advantages includes good sensitivity & good linearity at constant temperature. But the problem with s strong temperature dependence.

IV.FABRICATION

MEMS fabrication process based on the high volume of batch processing that includes addition or subtraction of two dimensional SI layers on the substrate. like photo resist, cvd, photolithography[7] and finally chemical etching. Therefore this leads to the 3-D device. Some of the additional layers can be added using a different types of thin-film deposition and bonding as well as by etching can be done by sacrificial "spacer layers"[7].

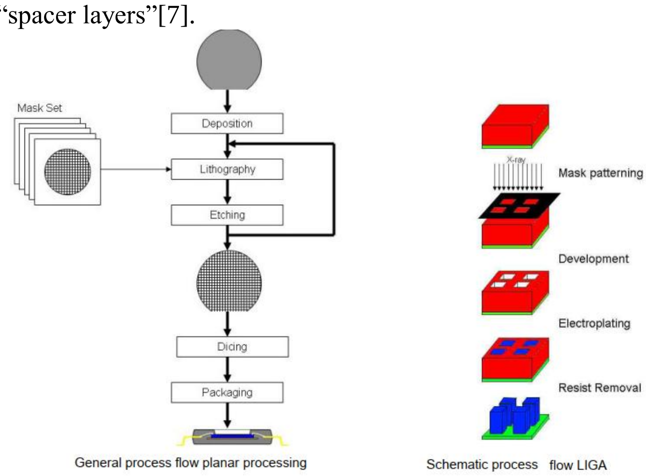

Fig 2: Design and fabrication flow of mems sensor

The flow chart represents the steps to simulate for designing the mems sensor. Based on the functionality required by the customer, the design engineer consider some of the secondary aspects like power, area, delay, size of the component and is simulated under the micro meter technology. where the design depends on λ based, DRC rules by defining the functionality. Fig 3 represents the synthesis flowchart given below.

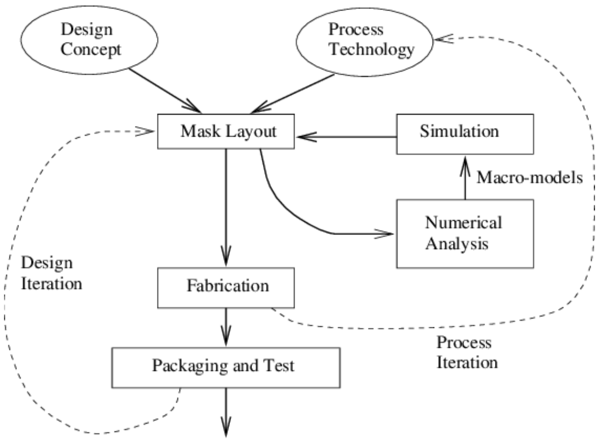

Fig 3: synthesis flow chart of Mems fabrication Process

a. **Photolithography:**

Photolithography is the process of photographic technique to transfer the copies of a master pattern on a silicon wafer Usually a circuit layout or design on IC, on the surface of a substrate of some a silicon wafer.

b. **Etching** :

Silicon etching is an primary step in the designing process of bulk & surface micromachining. It is is not only to create the base structures trench of sand cavities [7,8], but also to release the cantilevers and membranes. This final etching or sacrificial layer [8] involves the undercutting by etching of a structure.

c. **Chemical Vapor Deposition:**

A CVD process is used to create the high-purity and high-performance of solid materials. This process includes, the substrate is exposed to one or more volatile, which will react and/or decompose on surface of the substrate to produce the desired deposition.

V, APPLICATIONS, MARKETS, INDUSTRIALIZATION

High volume & wide verity of MEMS can be found in diversified applications crossways multiple markets (Table 1). In the perspective of rising technologies, MEMS products were initially concentrated on technology-product paradigm rather than the product-market. Subsequently MEMS devices were found numerous applications across the wide verity of industries.. some of the example, MEMS accelerometer initially used in launching application in airbag sensors, and further in the applications automotive sector such as Electronic Stability Program (ESP) and rollover detection. Therefore the technological advancements were moved a head and finally the production costs reduced and the sensors and other components became affordable for consumer applications. In parallel to this the accelerometer sensors were introduced in most preferred applications such as commercial and medical applications. The following table 1 indicates the detailed description of current and potential applications within each market segment for future applications.

Table 1: Wide verity of MEMS with application in real world

Consumer electronics	Medical	Communications	Aerospace, defence	Automotive
Inertial sensors	Pedometer, game control, image stabilization in video camera's, hard disk protection	Motion tracking, pacemaker	Missile guidance, navigation, laser range finder	Airbags, vehicle dynamic control, navigation systems, active suspension, roll detection
Optical devices	Micro-displays, autofocus lenses	Micro spectrometers for patient self testing/ monitoring	Variable optical attenuators, optical switching, tuneable filters	Micromirrors in bar code readers and projectors
RF MEMS	Tunable capacitors and resonators for mobile phones, switches in base stations	Switches and tuneable capacitors for radar and communications	Switches, relays, resonators, Effuses	
Micro phones	Mobile phones, note books, camcorder	Hearing aids	Hands free calling	
Micro fluidic devices	Inkjet heads	LOC for Point of Care and micro needles , insulin , analytics, pumps	Gas and liquid chromatography, spectrometer micro , micro cooling & reactors	
Pressure sensor	Hiking altimeters, scuba gear	Blood pressure, kidney dialysis, breathing	Flight control systems, cabin pressure, hydraulic systems	Manifold Air Pressure, Tire Pressure maintaince Systems
Flow sensor	Test function,	Air intake & air quality in cabins		
IR sensors	Cabin temperature control, prevention from crash, anti fog & seat occupancy, break ,tire monitoring	Thermo-meter, diagnostic	Security monitoring,	white goods count and maintaince, industrial HVAC control Humidity , Ventilation, Air Conditioning
Others	Fingerprint sensors for authentication		Probe cards for electrical testing	

VI. ANALYZING AND PREDICTING FUNCTIONALITY OF MEMS IN AUTOMOTIVE INDUSTRY

Now a days a wide verity of sensors are applied to increase the performance of automobile industry in view of control safety, security and of the maintenance. Apart from that future prediction is depends on the present and the past conditions of the system. Mems are an device which can accept the information based in the angle rotation. Each degree of input can be applied as input and applied to the controller or processor. Based on the condition provided in the electronic control unit the output related to the sensor is provided.

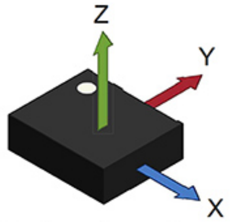

Fig 4: angle based Mems sensor

a. Existing system:

Most of the present low end Indian automotive manufacturing industry [10-11] presently facing problems with safety and security issues. Due to this there are large amount of road accidents, which leads to many deaths or accidents as showed in the bar chart as showed in fig 5

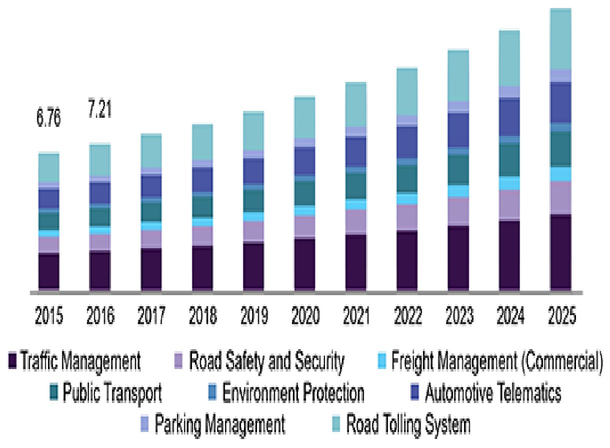

Fig 5: Year wise road accidents in India

b. Proposing Methodology/method

Block diagram

The proposing models describe the safety and security system that can helps the automotive sector [10-11] to reduce the road accidents at most. Based on the input from the MEMS motion sensor ie angle is converted into voltage, based on the action written in the electronic control, the decision will be taken and the respective output device will be controlled.The RF section convey any the same information to the next near by vehicle, in which the second vehicle can takes the immediate action to prevent the accidents.

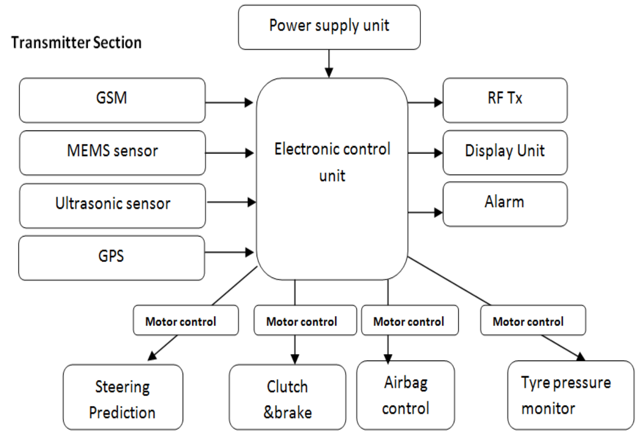

Fig 6: Transmitter block diagram

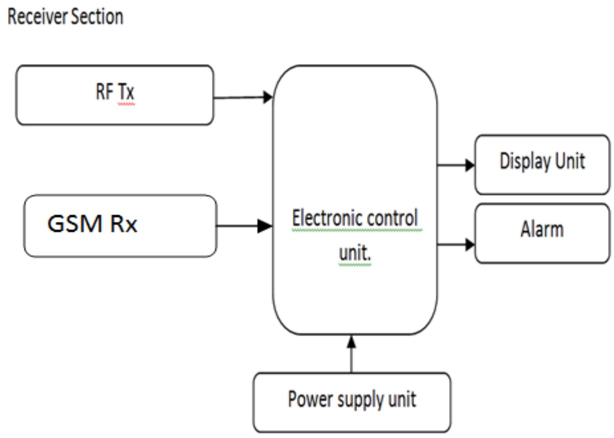

Fig 7: Receivers block diagram

Based on the information provided from the Transmitter the receiver will get the data from the RF receiver in the form of electromagnetic signal and converted digital information ADC, based on the instruction written in the controller, respective action will be performed.

Results:

Fig 8: Mems sensor with sensor Transmitter section

Fig 8 indicates the angle changed from 0 to 90 degree therefore the steering control is applied after identifying the data from the ultrasonic sensor.

Fig 9: Display unit with receiver unit

Information across the devices can be indicated by 16*2 seven segment display, connected in serial communication mode of operation. if the amount of angle is more than the threshold value, Rf transmitter send the information to the receiver and it indicates the display as well as alarm. it is a precautionary action to be performed across the receiver indicated in the fig:9.

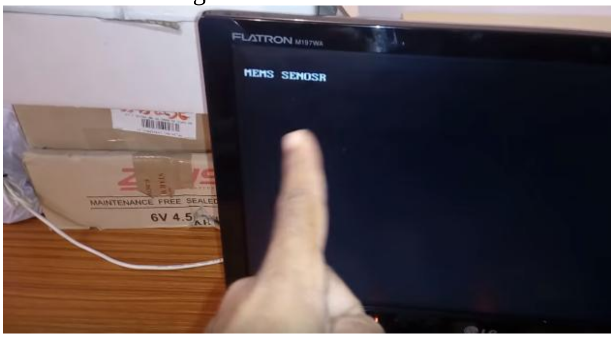

Fig 10: Serial communication mode via display

Using serial communication port (RS232) the informatio n and the information can be visualized in the monitor of its Coordinates (Longitude and latitude) can be projected in Fig 10.

Fig 11: Controlling of Receiver end unit

On the other end of the receiver, actions are completely depends on the performance or the functionality of the Transmitter, the above Fig 11 indicates when the mems angle is changing, the respective moment of steering control or applying the clutch and brake or airbag open or the tyre pressure can be monitored based on the input data provided by ultrasonic sensor.

Flow chart:

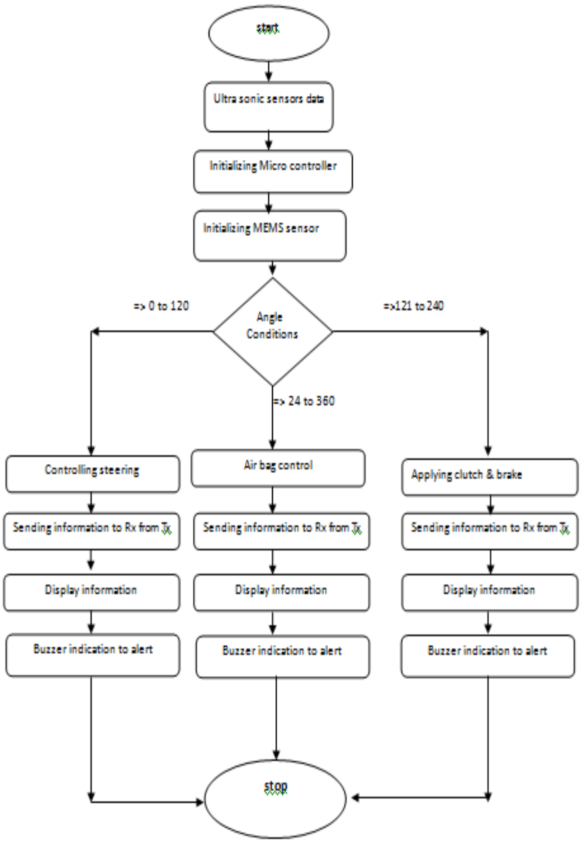

Fig 12: flow chart of functional view

From the flow chart Fig 12, we can understand the complete operation is depends on the angle of the MEMS sensor and also communication between Tx and Rx is performed or Via GSM.

Fig 13: communication between multiple units

Fig 13 indicates the real time scenarios, when the ambulance is passing on the way, every road has to blocked, except road in which it is passing. Before it is passing the control unit has to give information to the signal post ,in which route it is coming. Therefore the control the traffic lights converts to RED. By this the ambulance can pass through without any problem. The complete action is depends on the angle, that is produced by MEMS device.

VII. APPLICATIONS:

In today's world, the automotive[10-11] and electronics sector is the most demanding & satisfying the customer segment.

A wide verity of application right from authentication, security, control and maintenance, prediction and preventive mechanism can be done by mems sensor. The graph model indicates the amount of growth in every year as showed in the fig 14

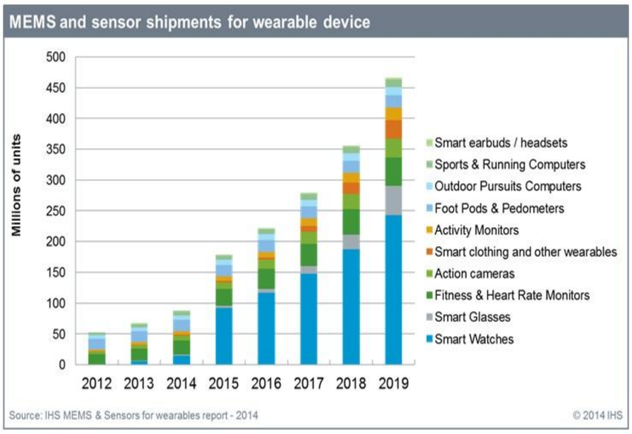

Fig 14: Potential Market for smart MEMS Sensor

Future scope:

From the existing models or literature it indicates that mems devices are having bright applications irrespective of the domain. Especially when it comes to the multidisciplinary, MEMS devices or the sensor has tremendous growth in near future. Some examples quotated here are smart living, remote metering, smart homes, smart utilities, alarm and surveillances, health care and assistance systems, smart agriculture, assistive devices, public safety and security.

VIII. CONCLUSION

The Research papers describe the process of MEMS functionality, design, manufacturing and fabrication techniques, that were employed. The systematic representation of 2D & 3D were described clearly. Classification is made based on sensing domain, clinical and diagnostic applications also described the applications based on sensitivity and temperature. Micro Electro Mechanical Systems (MEMS) fabrication process of photolithography, etching, and chemical vapor deposition were clearly described in the fabrication process. Some of the applications were encountered. MEM is a technology which makes the application in simple in where the amount of power consumption is less based on design, fabricating, and handling of micron-sized systems A technique which combines the both electrical and mechanical components together on a single chip, to produce a system of miniature dimensions. An intelligent system, that has miniaturized machines(single substrate/package/unit) that combining sensors, actuators, signal processors, communication systems etc., Keeping many of the significant features of MEMS and the need of exploring new possibilities are enriching the existing technologies of the MEMS based devices. In future a wide spread of application in the field of electronic, medical, mechanical, automotive, networking, material science can be increased. Therefore the performance and efficiency of the system can be enriched with help of MEMS integrated sensors.

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