AN OVERVIEW OF MICRO ELECTRO MECHANICAL SYSTEMS (MEMS)

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Abstract - MEMS is relatively a new technology which exploits the micro electronics infrastructure to create complex machines of micron feature size with continuously increasing capability and performance, with the outcome of MEMS technology large, expensive, complex systems have been replaced by small, high performance, inexpensive integrated circuits. Products with MEMS devices perform faster and are more reliable. This paper outlines the working, production, benefits, applications and challenges of MEMS technology. This paper also gives idea on how MEMS technology has brought revolutions in various fields like automotives, consumer electronics, medicine, computer market etc.

Index Words: MEMS, Sensors, Nanotechnology, Integrated Circuits, Motion, IC Chips, Automation.

I. INTRODUCTION

Micro Electro Mechanical Systems (MEMS) is a technology that has been largely adopted from the Integrated Circuit (IC) Industry and applied to the miniaturization of all systems not only electrical but also mechanical, optical, fluid, magnetic etc. MEMS constitute mechanical as well as electrical components on a single chip. Electrical components on the chip process data while mechanical elements act in response to that data hence a complete system on a chip. These tiny devices have elements ranging in size from 1-100 microns above the thickness of human hair.

Even though MEMS are adopted from IC Industry, there’s a whole lot of difference between MEMS and ICs. These chips do not have a basic building block where as a transistor is the basic unit or building block of IC. MEMS devices are generally divided into two categories microscopic sensors and actuators. Sensor devices gather information from their surroundings and actuators execute given commands or acts generally through highly controlled movements. Also known as MST OR Micro Systems Technology in Europe and Asia, the potential for MEMS technology is endless. MEMS technology reduces cost, power consumption, bulk and weight while increasing performance, production volume, and functionality by orders of magnitude. For example, one well known MEMS device is the MEMS crash sensor known as MEMS accelerometer (it’s now being manufactured using MEMS low cost, small size, more reliability, shown in Fig 1). They measure the force of an automobile crash and deploy an air bag if the force is great enough. Also with the help of MEMS print heads, inkjet printers have developed from crude slow black and white devices to fast flexible photographic quality images.

Fig 1: MEMS Accelerometer

II. BACKGROUND

The first MEMS products were developed in the 1960s, when accurate hydraulic pressure sensors were needed for aircraft. MEMS technology has become so wide spread since its beginning in 1980. It is estimated that there are now between 15-20 MEMS devices for every person living in North America. In the late 80s, MEMS accelerometers for car airbags were developed as a less expensive, more reliable, and more accurate replacement for conventional crash sensor. Taking the spotlight today are optical MEMS (also known as Micro Opto-Electro Mechanical Systems or MOEMS) primarily micro mirrors, which are used as digital light processors in video projectors and as well as switches in optical network equipment. After extensive development, today’s commercial MEMS – also known as Micro System Technologies (MST), Micro Machines (MM), or M3 (MST, MEMS & MM) – have proven to be more manufacturable, reliable and accurate, dollar for dollar, than their conventional counterparts. However the technical hurdles to attain these
accomplishments were often costly and time-consuming, and current advances in this technology introduce newer challenges still. Because this field is still in its infancy, very little data on design, manufacturing processes or liability are common or shared.

III. HOW MEMS ARE MADE:

MEMS are using the basic fabrication techniques and materials of micro-electronics’. Thin layer of material of materials are deposited on to the base and then are selectively etched away leaving a microscopic 3-dimensional structure as shown in fig 2.

Fig 2: 3-d structure.

The process of steps used for making of MEMS is same as the process of steps used for making of IC’s as shown in fig 3.

IV. BENEFITS OF MEMS

Because of increase in micromachining technology, hundreds of MEMS can be made from a single 8-inch wafer of silicon. Below is an image which shows how small MEMS are in comparison to a dime. Because an entire system can be made this small and in such quantities, prices are reduced for products which incorporate this technology. MEMS also have no moving parts, so they are much more reliable than a macro system. Because of the reduced cost and increased reliability, there is almost no limit to what MEMS can be used for.

Fig 4: MEMS on a dime.

V. APPLICATIONS OF MEMS

MEMS find their applications in various fields due their benefits over other conventional machines/systems. Applications of MEMS in various fields are as follows:

Transducer:

A transducer is a medium for transforming energy between 2 or more domains. A transducer comprises of a sensor which measures something in its surrounding environment and provides a response related to the measured parameter and a mechanical actuator which converts electrical signals into a mechanical action.

Inertial Sensors:

Inertial sensors are mechanics sensors aiming at measuring accelerations, in the mechanics science definition. There are two categories of inertial sensors. They are, accelerometers which measures variation of translational speed and gyroscopes which measures variation of rotational speed.

Accelerometers:

Micro accelerometers were the first MEMS device to flood the market. Micro accelerometers measure variation of translational speed. So acceleration, deceleration, even very high deceleration, like…shock! The sensor that detects a shock and launches the airbag is a micro accelerometer combined with an electronic circuit able to decide whether or not the shock was an accident or just your car passing a pothole. The core of the
MEMS accelerometer has a central mass that moves in response to a vehicle’s acceleration. This inertial mass is mounted on a hinge that limits its movement and returns to central position when at rest. The electrical sensors read the data and the microprocessor monitors the state of the accelerometer in motion. In collision, there is a sudden change in acceleration. When this change exceeds an unsafe level, air bags are deployed. The entire process takes only a fraction of a second and has saved millions of lives.

MEMS technology allows crashed sensors on one or two simple chips. Earlier systems needed many electrical and mechanical components located throughout an automobile measuring the same data. Reducing the number of components increases the accuracy and lowers the cost of these systems. There are lots of applications, like navigation, micro accelerometers can help in increasing precision. There are more and more to say about micro accelerometers, they are still the spearhead of MEMS industry. The figure shows a accelerometer that is used normally in cars and other vehicles.

Digital micrometer device:

The MEMS micrometer device is used in modern video projectors, home theatres and televisions. This chip uses microscopic moving mirrors to improve the image quality and overall reliability of these products. In colour systems, projectors can create over 16 million shades of colour. These systems are producing high quality images that they are now being installed in movie theatres replacing film projectors.

Consumer Electronics Market:

In the consumer electronics market, acoustic MEMS chips are changing the way sound reaches our ears through cell phones, personal stereos and hearing aids providing less distortion and higher quality and clarity. MEMS digital micrometer controls light. In video projectors in offices around the world are now able to produce laser sharp bright colourful images. Sensors are used in sports training devices, computer peripherals, car and personal navigation devices and also in active subwoofers

Computer market:

In the computer market, MEMS is revolutionizing mass data storage by miniaturizing components for disk drives, sensors and peripherals meeting the increasing needs for low cost high capacity digital storage.

Military:

MEMS products are used in a wide range in tanks, planes, equipment for soldiers for military purposes.
Biotechnology:

MEMS enabling new discoveries in science and engineering such as the polymerase chain Reaction (PCR) Microsystems for DNA amplification and identification, micro machined scanning Tunnelling microscopes (STMs). Biochips for detection of hazardous chemical and biological agents, and Microsystems for drug screening and selection.

Fig 8: scale showing up to nanometers.

Communications:

High frequency circuits will benefit considerably from advent of RF-MEMS technology. Electrical components such as inductors and tuneable capacitors can be improved significantly compared to their integrated parts if they are made using MEMS technology. With the integration of such components, the performance of communication circuits will improve, while the total circuit area, power consumption and the cost will be reduced. The MEMS technology has the potential of replacing many radial frequency components such as switches phase shifters, capacitors, inductors, and filters, used in today’s mobile, communication and satellite systems.

Medicine:

Fig. 8 MEMS needle within the opening of a hypodermic needle.

In medicine, the advent of MEMS chips for drug delivery can benefit any patient who must follow a regimen for medication. A Single chip embedded in patient can release correct amount of drug over a given period of time. There have been many efforts to bring MEMS eye contact lens in the near future.

Fig 9: MEMS lens.

Space Science:

In addition, MEMS are well suited for the needs of space exploration and thus will play an increasingly large role in future missions to the space. Using the GPS satellites, one can easily know the position using the landmarks like the sun or a star or two other GPS satellites.

NASA used the term Nano satellite in 1998 to describe a satellite which weighs less than 10kg. Pico Satellites weigh less than 1kg. Femto Satellites weigh less than 0.1kg Micro Satellite less than 100kg...

Fig. 9 MEMS in Space Science (GPS Satellite with MEMS Sensors)
VI. COMPARISON

![Graph showing MEMS Market by Application]

Fig. 10 MEMS Market by Application

VII. CURRENT CHALLENGES:

MEMS is currently used in low or medium-volume applications. Some of the obstacles preventing its wider adoption are:

- **Limited Options:**
  
  Most companies who wish to explore the potential of MEMS have very limited options for prototyping or manufacturing devices, have no capability or expertise in micro fabrication technology. Few companies have their own fabrication facilities because of high cost.

- **Fabrication Knowledge Required:**

  Currently designer of a MEMS device requires a high level of fabrication knowledge in order to create a successful design. Often the development of even the most mundane MEMS device requires a dedicated research effort to find a suitable process sequence for fabricating it.

- **Packaging:**

  MEMS packaging is more challenging than IC packaging due to the diversity of MEMS devices and the requirement that many of devices be in contact with their environment.

VIII. CONCLUSION:

MEMS is an emerging technology which will rapidly revolutionize all the fields if the level of fabrication knowledge of current designer of MEMS devices and the packaging techniques are still improved. MEMS technology will continue to quietly improve life as we move into the future.

IX. REFERENCES


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