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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (18): 4498-4502, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.4498.4502
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Distinct Advantages and New Applications in Mems

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Abstract: Demands for MEMS are continuously growing and it is predicted that they will continue to grow for a few more decades with the value of products rising to $40 billion in 2015 and $200 billion in 2025. In this study, we first discuss the main distinct advantages of MEMS as well as the important differences between MEMS and IC, then some latest research progresses on biomedical, optical and automotive applications of MEMS are reviewed. Finally, possible future developments of MEMS are prospected.

Key words: MEMS, IC, sensor, biomedical, optical, automotive, application

INTRODUCTION

The acronym MEMS stands for Micro Electro Mechanical Systems with the focal point being the second "M"(mechanical) and thence ultimately the concluding "S". MEMS are integrated micro-scale systems combining electrical optical or other (magnetic, mechanical, thermal, fluidic, etc.) elements typically fabricated using conventional semiconductor batch processing techniques, namely, MEMS are macro-engineering at microscale, they have two main features: (1) dDesign structures/devices/systems at micro/nano scale, (2) Typical microsystems involve multiple physical domains. These systems are designed to interact with the external environment either in a sensing or actuation mode to generate state information or control it at a different scale (Korvink and Paul, 2006; Jha, 2008). MEMS are the exotic cousins of semiconductors and integrated circuits (ICs), originally based on silicon wafer fabrication techniques but adding the dimensions of space, flexion and continuously variable output similar to analog devices.

Some of the key advantages of MEMS (Gad-El-Hak, 2006; Ghodssi and Lin, 2011):

- The ability to miniaturize physical interactions to nearly the same degree as IC's
- The related ability to reduce the sample-size of measurands
- The ability to integrate sensing, analysis and response in a miniature package

MEMS is not a single product or market but an engineering tool-kit applied to a wide array of markets. Simpler but by no means trivial, sensing devices (pressure, inertial, thermal, etc). are finding more diverse applications and finally emerging into consumer markets, such as accelerometer and gyroscopic MEMS devices for the iPhone, Wii and Playstation game controllers. Within these MEMS, we typically see integration on a single silicon substrate of not just electronic devices as on the chips but also mechanical elements, sensors and actuators. In addition to the commonly present materials in silicon Ics, other materials such as ceramics and most recently carbon nanotube (CNT) arrays are also being incorporated into MEMS. The resulting microsystems have shown for a variety of applications, unprecedented levels of miniaturization, reliability and new capabilities (Setter, 2009; Hartzell *et al*., 2010; Gusev *et al*., 2010; Aggarwal *et al*., 2010; McWilliams, 2011; Kempe, 2011; Magrab, 2012).

MEMS VERSUS IC

MEMS are a class of physically small systems that combine electronic functions with optical, mechanical, thermal and others. MEMS encompass the process-based technologies used to fabricate tiny integrated devices. MEMS are a logical extension of microelectronics and IC technology. As an extension of IC technology, the production of MEMS devices benefits from years of IC manufacturing experience. For instance, technologies such as microlithography, chemical etching, vapor deposition and electroplating can be used to create the microstructures of MEMS. The products range in size from a few micrometers to millimeters. These devices /systems have the ability to sense the environment, process and analyze information and respond with a variety of mechanical and electrical actuators on the micro scale and generate effects on the macro scale.

As a manufacturing technology, MEMS has several distinct advantages (Gad-El-Hak, 2006; Ghodssi and Lin, 2011):

- MEMS technology has the characteristics of interdisciplinary. Its diversity of applications has led to an unparalleled range of devices and synergies across previously unrelated fields, for instance, biomedicine and microelectronics, semiconductor physics and microoptics
- By MEMS technology and batch fabrication techniques, one can produce components and devices with higher performance and reliability, such products have obvious advantages with small size, light weight and low cost
- MEMS technology provides the basis for the fabrication of products that cannot be manufactured by other methods. Hence, MEMS have become a universally applicable technology such as IC microchip

However, three points makes it very different (Gad-El-Hak, 2006; Ghodssi and Lin, 2011):

- MEMS products are usually application specific, resulting in a wide range of very different products
- The number of MEMS products will be always less than that for semiconductor IC's. A good example is the inkjet printer. The four inkjet nozzles are operated using printed circuit boards with tens of other silicon devices
- Unlike IC manufacturing, there is no "unit cell" (like the transistor) in MEMS technology. This leads to a more diverse technology base with more development and engineering work. Hence, it is more expensive and more difficult to maintain MEMS technology

Some important differences between MEMS and IC are summarized in Table 1. There is also lack of a stable front-end technology, no Complementary Metal-Oxide Semiconductor (CMOS) equivalent) in MEMS. Moreover, there is a multidimensional interaction space in MEMS, for instance, there is not only electrical connections but also optical connections. MEMS are a very complicated multidisciplinary field, in which physics, chemistry, materials science, mechanics and engineering play an important role. In addition, the end-product functionality of MEMS is often tightly related to the process used to make it. This can be vividly expressed as "one product, one process". At this point the MEMS are completely different with the IC industry where so many products share a common process.

Therefore, the current research is evolving toward a "MEMS unit" that is not a single "unit cell" (e.g. transistor in IC) but small, specifically designed, components libraries that could be refined over time to become "standard building blocks" for each MEMS device domain.

MEMS technology is a enchanting and far-reaching area. It has played and will continue to play a very vital role in both science and human society. Especially, it has translated physical properties and material characteristics into structures and devices that can have a large positive impact on people's everyday life.

SOME RECENT APPLICATIONS OF MEMS

Until recently, sensors are a major application for MEMS devices. There are three primary MEMS sensors, i.e., pressure sensors, chemical sensors and inertial sensors. For instance, MEMS inertial sensors are designed to sense a change in an object's inertia and then convert inertial force into a measurable signal. They measure changes in acceleration, vibration, inclination and orientation. Compared to the macro device, a MEMS provides a quicker response to rapid deceleration and more reliable functionality. It is cheaper and smaller in size. In this section, we focus on some new applications of MEMS in three fields.

Biomedical Applications of MEMS MEMS technology is an engineering solution for biomedical problems. From component aspect, BioMEMS is the research of micro-fabricated devices for biomedical applications. BioMEMS usually contains sensors, actuators, mechanical structures and electronics. Such systems are being developed as diagnostic and analytical devices at diagnostic and analytical devices.

In medical field MEMS have the following applications (Wang and Soper, 2007):

- Precise dispensers for small amounts of liquids found in needleless injectors and drug delivery systems
- Sub-dermal glucose for monitoring monitor glucose levels and delivery of the insulin
- DNA microarrays for testing of genetic diseases and other biological markers
- Medical diagnostics for blood analysis, cells counts and urinalysis

Table 1: Important differences between MEMS and IC

	MEMS	IC
Unit cell	No unit cell	Transistor
Front-end technology	No single stable technology	CMOS
Interaction space	Multidimensional	Electrical
Basic disciplines	Multidisciplinary	Physics and engineering
Process or fabrication technology	One product, one process	Many products share a common process

Table 2: Comparing MEMS with BioMEMS

MEMS	BioMEMS
Silicon based material	Biocompatible material
Electrical and mechanical interface integration	Biomolecular and physical parameter (electrical,mechanical,optical) transducer integrationMoving part
in micromachining system-active component	Motion medium in passive substrate-microfluidic driving force

- Polymerase chain reaction (PCR) for DNA replication

In particular, pressure sensors in biomedical field have the following applications:

- Blood pressure sensors
- Intracranial pressure sensor
- Pressure sensors in endoscopes
- Sensors for infusion pumps

Main differences between MEMS and BioMEMS are summarized in Table 2. BioMEMS encompasses all interfaces and intersections of the life sciences and clinical disciplines with microsystems and nanotechnology. Main related areas are the following (Bhansali and Vasudev, 2012):

- Micro and nanotechnology for drug delivery
- Tissue engineering, harvesting, manipulation
- Microfluidics and miniaturized total analysis systems
- Nano-scale imaging and integrated systems
- Biomolecular amplification
- Sequencing of nucleic acids
- Molecular assembly
- Proteomics
- Biosensors

Optical Applications of MEMS Optical MEMS originated from fusion of three technologies, i.e., integrated circuit (micro-electronics), semiconductor laser (micro-optics) and resonant gate transistor (micro-mechanics). Its objective is to integrate optical, mechanical and electronic functions into one device (Liu, 2008).

Optical MEMS can offer:

- Low optical insertion loss
- Low power consumption
- Low crosstalk

Tremendous progresses have been made in optical MEMS, especially they have already been quite successful in display technologies. For instance, Texas Instrument's Digital Mirror Devices (DMD) have been used in a variety of projection systems including video projection and digital cinema.

In the last decade, telecommunications have become the market driver for optical MEMS. The demand for routing internet traffic through fiber optic networks pushes the development of both digital and scanning micro-mirror systems. However, mechanical stability and millisecond-scale response time are challenges of the optical MEMS switches for practical optical communications networks.

In the biomedical arena, micro-optical scanners promise low-cost endoscopic 3D imaging systems for *in vivo* diagnostics.

Integrations are the new trends in optical MEMS, the following ones are particularly potential (Zhou *et al*., 2012; Solgaard, 2008):

- Higher level of integration, less free-space alignment
- Mems-Planar Lightwave Circuits (PLC) integration
- MEMS-nanophotonics integration
- Electronics integration
- Single-chip optical MEMS system

Automotive Applications of MEMS Sensors and actuators are components of automotive electronic control systems, their design has increasingly made use of MEMS technology. The functional groups of sensors, actuators, controller and software form the backbone of present and future automotive systems.

In the last decade, there has been an ever increasing penetration of electronic control systems and electrical components in automotive products. These systems can be categorized into the areas of powertrain and chassis control, comfort and convenience and communications. In order to make the system application viable, each of them requires a specific set of low-cost sensors and actuators. At present, the main automotive applications of MEMS are the following (Malcovati *et al*., 2009):

- GPS and inertial navigation system
- Accelerometer for airbag deployment
- Microphones for noise cancellation
- Exhaust gas sensor
- Corrosion sensor
- Tire pressure sensor
- Brake pressure sensor and control
- Accelerometer for suspension control
- Mass air flow pressure sensor
- Air conditioning pressure sensor
- Silicone Nozzles for fuel injection
- Fuel injector pressure sensor

In particular, the widely used MEMS inertial sensors in automobiles are the following:

- Airbag deployment
- Smart sensors for collision avoidance and skid detection
- Active suspension
- Automobile navigation
- Antitheft system
- Headlight leveling and positioning
- Rollover detectors

FUTURE DEVELOPMENTS OF MEMS

The future of MEMS is integrally linked to market trends in general and driven by the increasing demand to monitor and control our environment. Undoubtedly, this demand does lead to the need for more sensors in cars, more sensors in industrial equipment and installation and, more sensors for our ambient intelligence. In order to avoid the need for a multitude of wires, such sensors must be self sustaining and able to communicate wirelessly (Ghodssi and Lin, 2011).

One growth area for MEMS sensors will be the evolution of "clean-tech" applications. Mesh sensor networks, such as commercial building automation, medical monitoring and industrial monitoring and control are areas of interest that can utilize MEMS sensor technology to sense pressure, air flow, position and orientation. MEMS could also play a role in energy harvesting to convert ambient vibration energy into electrical energy through piezo or capacitive energy conversion (Ballas, 2007).

In addition, national security is of increased importance related to the growing fear from terrorist attacks and outbreaks of infectious human or animal diseases. This drives a need for small multi parameter instruments to test water, air, blood and so on for microbiological threats (Ilyas and Mahgoub, 2006).

On the other hand, there is a tendency to develop more flexible and cheaper production technologies. It is expected that this tendency will be driven by the production research into typical low cost, large surface area devices (for instance, solar cell, displays, wearable electronics) and disposable diagnostics devices.

Finally, a huge number of products will originate from the large amount of nanotechnology research investments, in many cases MEMS will act as an interface between the nano and human size world (Gusev *et al.*, 2010; McWilliams, 2011; Magrab, 2012).

ACKNOWLEDGMENT

This work was partly supported by the National Science and Technology Support Program of China under Grant No.2012BAC20B09.

REFERENCES

Aggarwal, P., S. Zainab, N. Aboelmagd and E. Naser, 2010. MEMS-Based Integrated Navigation. Artech House, UK.

Ballas, R.G., 2007. Piezoelectric Multilayer Beam Bending Actuators: Static and Dynamic Behavior and Aspects of Sensor Integration. Springer, USA.

Bhansali, S. and A. Vasudev, 2012. MEMS for Biomedical Applications. Woodhead Publishing Limited, Cambridge, UK., ISBN: 9780857091291, Pages: 487.

Gad-El-Hak, M., 2006. The MEMS Handbook. CRC Press, USA.

Ghodssi, R. and P. Lin, 2011. MEMS Materials and Processes Handbook. Springer, USA., ISBN: 9780387473185, Pages: 1224.

Gusev, E., E. Garfunkel and A. Dideikin, 2010. Advanced Materials and Technologies for Micro/ Nano-Devices, Sensors and Actuators. Springer, USA., ISBN: 9789048138050, Pages: 314.

Hartzell, A.L., M.G. da Silva and H.R. Shea, 2010. MEMS Reliability. Springer, USA.

Ilyas, M. and I. Mahgoub, 2006. Smart Dust: Sensor Network Applications, Architecture and Design. CRC Press, USA., ISBN: 9780849370373, Pages: 352.

Jha, A.R., 2008. MEMS and Nanotechnology-Based Sensors and Devices for Communications, Medical and Aerospace Applications. Taylor and Francis, USA., ISBN: 9780203881064, Pages: 432.

Kempe, V., 2011. Inertial MEMS: Principles and Practice. Cambridge, UK.

Korvink, J.J.G. and O. Paul, 2006. MEMS: A Practical Guide to Design, Analysis and Applications. Springer, USA.

Liu, A.Q., 2008. Photonic MEMS Devices: Design, Fabrication and Control. CRC Press, USA.

Magrab, E.B., 2012. Vibrations of Elastic Systems: With Applications to MEMS and NEMS. Springer, USA., ISBN: 9789400726727, Pages: 505.

Malcovati, P., A. Baschirotto, A. D'Amico and C. Natale, 2009. Sensors and Microsystems. Springer, USA.

McWilliams, A., 2011. MEMS: Biosensors and nanosensors. February, 2011, BCC Research.

Setter, N., 2009. Electroceramic-Based MEMS: Fabrication-Technology and Applications. Springer, USA.

Solgaard, O., 2008. Photonic Microsystems: Micro and Nanotechnology Applied to Optical Devices and Systems. Springer, USA.

Wang, W.J. and S.A. Soper, 2007. Bio-MEMS: Technologies and Application. Taylor and Francis, USA.

Zhou, Z.Y., Z.L.Wang and L.W. Lin, 2012. Microsystems and Nanotechnology. Springer, USA., ISBN: 9783642182938, Pages: 1026.