MEMS & Its Applications: An Introduction

Dr. Manoj Sharma
Deptt.of ECE, GianiZail Singh Campus College of Engineering & Technology (MRSPTU, Bathinda), Bathinda
neelmanoj@gmail.com

Abstract--**In this paper we present general idea of microelectromechanical system (MEMS) design and its application is the technology of very small mechanical devices driven by electricity. The vital physical size of MEMS devices can vary from well below one micron on the lower end of the dimensional range, all the way to several milli-meters, it merges at the nano-scale into nanoelectromechanical systems (NEMS) and nanotechnology. MEMS are also referred to as micromachines (in Japan), or *micro systems technology – MST* (in Europe).**

Keywords: **MEMS, NEMS, MST, IMOD,SAM**

I INTRODUCTION

Micro-Electro-Mechanical Systems, or MEMS, is a technology that in its most universal form can be defined as miniaturized mechanical and electro-mechanical elements (i.e., devices and structures) that are made using the techniques of microfabrication. The serious 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 easy structures having no moving elements, to really complex electromechanical systems with multiple moving elements under the control of integrated microelectronics. The one main decisive factor of MEMS is that there are at least some elements having some sort of mechanical functionality whether or not these elements can move. The term used to define MEMS varies in different parts of the world. In the United States they are mostly called MEMS, while in some other parts of the world they are called "Microsystems Technology" "micromachineddevices"[2], [3], [4]–[6].

As shown in figure 1 the functional elements of MEMS are miniaturized structures, sensors, actuators, and microelectronics, the mostnotable (and perhaps most interesting) elements are the microsensors and microactuators. Microsensors and microactuators are appropriately categorized as "transducers", which are defined as devices that transfer energy from one form to another. In the case of microsensors, the device characteristically converts a measured mechanical signal into an electrical signal[1].

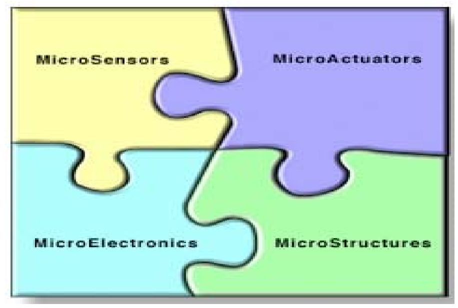

Figure 1 Functional Elements of MEMS [5].

Examples of MEMS device applications include inkjet-printer cartridges, accelerometers, miniature robots, microengines, locks, inertial sensors, microtransmissions, micromirrors, Microactuators, optical scanners, fluid pumps, transducers, and chemical, pressure and flow sensors. New applications are rising as the existing technology is applied to the miniaturization and integration of conventional devices [4]–[6],[12], [13], [14].

II HISTORICAL DEVELOPMENT OF MEMS

Over the past several decades MEMS researchers and developers have confirmed an extremely large number of microsensors for almost every promising sensing modality including temperature, pressure, inertial forces, chemical species, magnetic fields, radiation, etc. extraordinarily, many of these micromachined sensors have demonstrated performances exceeding those of their macroscale counterparts. That is, the micromachined translation of, for example, a pressure transducer, typically outperforms a pressure sensor made using the most particular macroscale level machining techniques. Not only is the performance of MEMS devices exceptional, but their method of production leverages the same batch fabrication techniques used in the integrated circuit industry – which can translate into low per-device production costs, as well as many other benefits. Accordingly, it is possible to not only achieve stellar device performance, but to do so at a comparatively low cost level. Not surprisingly, silicon based discrete microsensors were rapidly commercially exploited and the markets for these devices continue to grow at a rapid rate.

III Scope OfMEMS At Present

More recently, the MEMS research and advance community has demonstrated a number of microactuators counting: microvalves for control of gas and liquid flows; optical switches and mirrors to redirect or modulate light beams; independently controlled micromirror arrays for displays, microresonators for a number of special applications, micropumps to develop positive fluid pressures, microflaps to modulate airstreams on airfoils, as well as many others. Surprisingly, even though these microactuators are extremely small, they frequently can cause effects at the macroscale level; that is, these tiny actuators can perform mechanical feats far larger than their size would imply. For example,as shown in figure2 researchers have placed small microactuators on the leading edge of airfoils of an aircraft and have been able to steer the aircraft using only these microminiaturized devices.

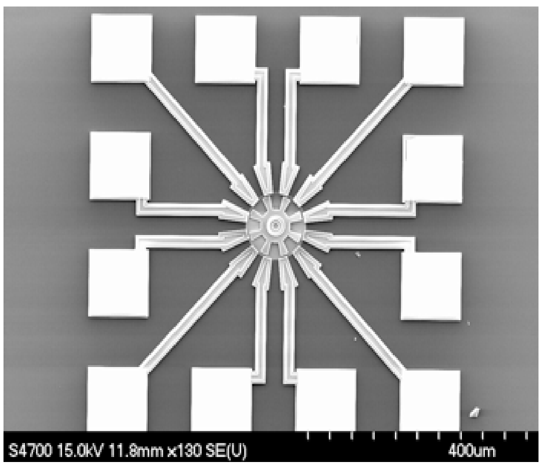

Figure2
A Surface Micromachined Electro-Statically-Actuated Micromotor Fabricated by The MNX. [5].

The real potential of MEMS starts to become fulfilled when these miniaturized sensors, actuators, and structures can all be merged onto a common silicon substrate along with integrated circuits (i.e., microelectronics). While the electronics are fabricated using integrated circuit (IC) process sequences (e.g., CMOS, Bipolar, or BICMOS processes), the micromechanical components are fabricated using compatible "micromachining" processes that selectively etch away parts of the silicon wafer or add new structural layers to form the mechanical and electromechanical devices. It is even more interesting if MEMS can be merged not only with microelectronics, but with other technologies such as photonics, nanotechnology, etc. This is sometimes called “heterogeneous integration.” Clearly, these technologies are filled with numerous commercial market opportunities.

While more complex levels of integration are the future trend of MEMS technology, the present state-of-the-art is more modest and usually involves a single discrete microsensor, a single discrete microactuator, a single microsensor integrated with electronics, a multiplicity of essentially identical microsensors integrated with electronics, a single microactuator integrated with electronics, or a multiplicity of fundamentally identical microactuators integrated with electronics. Nevertheless, as MEMS fabrication methods advance, the assure is an enormous design freedom wherein any type of microsensor and any type of microactuator can be complex with microelectronics as well as photonics, nanotechnology, etc., onto a single substrateas shown in figure3.

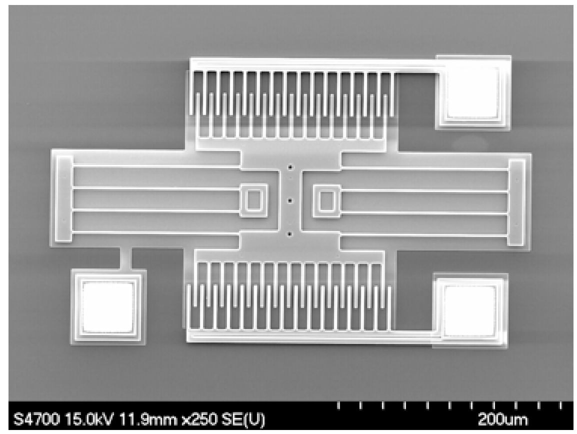

Figure3
A Surface Micromachined Resonator Fabricated by The MNX [5].

This apparition of MEMS whereby microsensors, microactuators and microelectronics and other technologies, can be integrated onto a single microchip is predictable to be one of the most important technological breakthroughs of the future. This will enable the development of smart products by augmenting the computational ability of microelectronics with the insight and control capabilities of microsensors and microactuators. Microelectronic integrated circuits can be thought of as the "brains" of a system and MEMS augments this decision-making means with "eyes" and "arms", to allow microsystems to sense and control the environment. Sensors gather information from the environment through measuring mechanical, thermal, biological, chemical, optical, and magnetic phenomena. The electronics then process the information derivative from the sensors and through some decision making capability direct the actuators to respond by moving, positioning, regulating, pumping, and filtering, thereby calculating the environment for some desired outcome or purpose. Furthermore, since MEMS devices are manufactured using batch fabrication techniques, similar to ICs, unparalleled levels of functionality, reliability, and complexity can be placed on a small silicon chip at a relatively low cost. MEMS technology is enormously diverse and fertile, both in its expected application areas, as well as in how the devices are designed and manufactured. Already, MEMS is revolutionizing many product categories by enabling whole systems-on-a-chip to be realized.

IV Relation Between MEMS & Nanotechnology

Although MEMS and Nanotechnology are sometimes cited as part and separate technologies, in reality the dissimilarity between the two is not so clear-cut. In fact, these two technologies are highly reliant on one another. The well-known scanning tunneling-tip microscope (STM) which is used to detect individual atoms and molecules on the nanometer scale is a MEMS device. Similarly the atomic force microscope (AFM) which is used to manipulate the placement and position of individual atoms and molecules on the surface of a substrate is a MEMS device as well. In fact, a variety of MEMS technologies are required in order to boundary with the nano-scale domain [10].

Likewise, many MEMS technologies are becoming dependent on nanotechnologies for successful new products. For example, the crash airbag accelerometers that are manufactured using MEMS technology can have their long-term reliability tainted due to dynamic in-use stiction effects between the proof mass and the substrate. A nanotechnology called Self-Assembled Monolayers (SAM) coatings are now routinely used to treat the surfaces of the moving MEMS elements so as to put offstiction effects from happening over the product's life [6].

Many experts have concluded that MEMS and nanotechnology are two different labels for what is essentially a technology surrounding highly miniaturized things that cannot be seen with the human eye. Note that a similar broad explanation exists in the integrated circuits domain which is frequently referred to as microelectronics technology even though state-of-the-art IC technologies typically have devices with magnitude of tens of nanometers. Whether or not MEMS and nanotechnology are one in the same, it is unquestioned that there are overpowering mutual dependencies between these two technologies that will only increase in time. Perhaps what is most important are the common benefits afforded by these technologies, including: increased information capabilities; miniaturization of systems; new materials resulting from new science at miniature dimensional scales; and increased functionality and independence for systems [14]

V Applications

In one viewpoint MEMS application is categorized by type of use.

- Sensor
- Actuator
- Structure

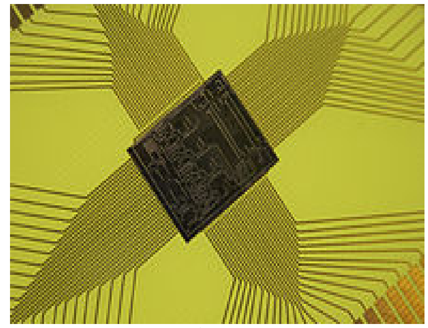

Figure4
Microelectromechanical Systems Chip[5].

In another view point MEMS applications are categorized by the field of application as shown in figure4 (commercial applications include):

- Inkjet printers, which use piezo-electrics or thermal bubble ejection to deposit ink on paper.
- Accelerometers in modern cars for a large number of purposes including airbag deployment in collisions.
- Accelerometers in consumer electronics devices such as game controllers (Nintendo Wii), personal media players /cell phones (Apple iPhone, various Nokia mobile phone models, various HTC PDA models)[15] and a number of Digital Cameras (various Canon Digital IXUS models). Also used in PCs to park the hard disk head when free-fall is detected, to prevent damage and data loss.
- MEMS gyroscopes used in modern cars and other applications to detect yaw; e.g., to deploy a roll over bar or trigger dynamic stability control
- Silicon pressure sensors e.g., car tire pressure sensors, and disposable blood pressuresensors
- Displays e.g., the DMD chip in a projector based on DLP technology, which has a surface with several hundred thousand micro mirrors
- Optical switching technology, which is used for switching technology and alignment for data communications
- Bio-MEMS applications in medical and health related technologies from Lab-On-Chip to MicroTotalAnalysis (biosensor, chemo sensor)
- Interferometric modulator display (IMOD) applications in consumer electronics (primarily displays for mobile devices), used to create interferometric modulation − reflective display technology as found in mirasol displays
- Fluid acceleration such as for micro-cooling

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 triumphant small firms offer value in innovative solutions and absorb the expense of tradition fabrication with high sales margins. In addition, both large and small companies work in R&D to explore MEMS technology[7]-[10].

VI The Future And Conclusion Of MEMS

Each of the three basic Microsystems technology processes we have seen, bulk micromachining, sacrificial surface micromachining, and micro molding/LIGA, employs a different set of capital and intellectual resources. MEMS manufacturing firms must choose which exactMicrosystems manufacturing techniques to invest in [14].

MEMS technology has the potential to change our daily lives as much as the computer has. However, the material needs of the MEMS field are at a preliminary stage. A thorough understanding of the properties of existing MEMS materials is just as important as the development of new MEMS materials.

Future MEMS applications will be driven by processes enabling greater functionality through higher levels of electronic-mechanical integration and greater numbers of mechanical components working alone or together to enable a complex action. Future MEMS products will demand higher levels of electrical-mechanical integration and more intimate interaction with the physical world. The high up-front investment costs for large-volume commercialization of MEMS will likely limit the initial involvement to larger companies in the IC industry. Advancing from their success as sensors, MEMS products will be embedded in larger non-MEMS systems, such as printers, automobiles, and biomedical diagnostic equipment, and will enable new and improved systems

References

[1]. MAtaka and H. Fujita, "*micro actuator array on a flexible sheet - smart mems sheet*", ieee26th international conference on micro electro mechanical systems (mems), pp 536-539, jan. 2013.

[2]. Binglei Wang and Shenjie Zhou; "*Size Dependent Pull-in Instability of Electrostatically Actuated Micro Beams based on MEMS*", Journal of Micromechanics and Microengineering, Vol. 21 No. 2, pp 304-309, Feb. 2011.

[3]. ZakriGhazalli, Asnulhadiahamad, MohdFazli Ismail and KhairulFikriMuhamad "*Design of Electrostatic Comb Actuators Based on Finite Element Method*" International Conference on Enabling Science and Nanotechnology, Malaysia, pp 1-3,Dec. 2010.

[4]. NduOsonwanne and Jason V. Clark *"MEMS Comb Drive Gap Reduction Beyond Minimum Feature Size: A Computational Study*"; Excerpt from the Proceedings of the COMSOL Conference, Boston, pp 317-322, 2010.

[5]. G.k. ananthasuresh, k.j. vinoy, k.n. bhat, s. Gopalakrishnanand v.k.aatre; "*micro and smart systems*" wiley –india; first edition, pp 115-129 2010.

[6]. J. Varona, E. Saenz, S. Fiscal- Woodhouse and A.A. amoui; " *Design and Fabrication of a Novel Microgripper Based on Electrostatic Actuation*" , 52nd IEEE International Midwest Symposium on Circuits and Systems, pp 827-832, Aug. 2009.

[7]. BadariahBais and BurhanuddinYeopMajlis; "*Low-g Area-changed MEMS Accelerometer using Bulk Silicon Technique*" American Journal of Applied Sciences vol.5, Issue 6, pp. (626-632), 2008.

[8]. Stephen A. Wilson a. And Renaud P.J. Jourdain "*New Materials for Micro-scale Sensors and Actuators: An Engineering Review*" Materials Science and Engineering R: Reports, Vol. 56, Issue 6, pp 119–129 2007.

[9]. W. Merlijn van Spengen and Erwin C. Heeres "*A Method to Extract the Lateral and Normal Component of the Motion from the Capacitance Change of a Moving MEMS Comb Drive*" Journal of Micromechanics and Microengineering, Vol. 17, No. 3, pp 447-451, 2007.

[10]. G. Somlay, Z. Szucs, A. Poppe and M. Rencz "*Simulation of a Comb Drive for Fracture Lifetime Measurements*" Excerpt from the Proceedings of the COMSOL Users Conference, Grenoble, pp 149-152, 2007.

[11]. Isabelle P.F. Harouche, C. Shafai and Richard Gordon, "*Design and Simulation of Microtweezers using a Controlled Displacement Comb Drive*" Canadian Conference on Electrical and Computer Engineering, Ottawa, pp 341-343, May 2006.

[12]. Kanchan Sharma, Isaac G. Macwan, Linfeng Zhang, Lawrence Hmurcik and XingguoXiong; "*Design Optimization of MEMS Comb Accelerometer" Sensors and Transducers*, Vol. 108, Issue 7, pp 15-30, 2006.

[13]. Isabelle P.F. Harouche and C. Shafai "*Simulation of Shaped Comb Drive as a Stepped Actuator for Microtweezers Application*" Sensors and Actuators A Vol.123–124, pp 540–546, March 2005.

[14]. Tai-Ran Hsu; "*Micro Assembly: A Technology on the Frontier of New Industrial Automation*" J. Microelectromech. Syst. Vol.10 Issue 2, pp1481–1490, 2005.