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Application for MEMS in Space

A. Katyal, Heena, Smiriti, M. Raja, S.K. Chaturvedi

Department of Aerospace Engineering, University of Petroleum & Energy Studies, Dehradun-248007, Uttrakhand, India.

1. Introduction

The domain of micro-electromechanical systems, or MEMS, encompasses the process-based technologies which are used to fabricate tiny integrated devices and/or systems that integrate functionalities from various physical domains into one device. Such devices are fabricated using a wide range of technologies, having in common the ability to create structures with micro- and even nanometer accuracies. The critical physical dimensions of MEMS products can vary from a few micrometers to several millimeters. These devices (or systems) have the ability to sense, control and actuate on the micro scale, and generate effects on the macro scale.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 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 “micro machined devices”.While the functional elements of MEMS are miniaturized structures, sensors, actuators, and microelectronics, the most notable (and perhaps most interesting) elements are the micro sensors and micro actuators. Micro sensors and micro actuators are appropriately categorized as “transducers”, which are defined as devices that convert energy from one form to another. In the case of micro sensors, the device typically converts a measured mechanical signal into an electrical signal.

2. Interdisciplinry Nature of MEMS

The interdisciplinary nature of MEMS relies on design, engineering and manufacturing expertise from a wide and diverse range of technical areas including integrated circuit fabrication technology, mechanical engineering, materials science, electrical engineering, chemistry and chemical engineering, as well as fluid engineering, optics, instrumentation and packaging. The complexity of MEMS is also seen in the extensive range of markets and applications that incorporate such devices. MEMS can be found in systems ranging from consumer electronics, automotive, medical, communication to defense applications. Current examples of MEMS devices include accelerometers for airbag sensors, microphones, projection display chips, blood and tire pressure sensors, optical switches, and analytical components such as lab-on-chip, biosensors and many other products.

More recently, the MEMS research and development community has demonstrated a number of micro actuators including: micro valves for control of gas and liquid flows; optical switches and mirrors to redirect or modulate light beams; independently controlled micro mirror arrays for displays, micro resonators for a number of different applications, micro pumps to develop positive fluid pressures, micro flaps to modulate airstreams on airfoils, as well as many others. Surprisingly, even though these micro actuators are extremely small, they frequently can cause effects at the macro scale level; that is, these tiny actuators can perform mechanical feats far larger than their size would imply.

3. Fabrication of MEMS Technology

MEMS, an acronym that originated in the United States, is also referred to as Micro System Technology (MST) in Europe and Micromachining in Japan. Regardless of terminology, the uniting factor of a MEMS device is in the way it is made. While the device electronics are fabricated using `computer chip' IC technology, the micromechanical components are fabricated by sophisticated manipulations of silicon and other substrates using micromachining processes. MEMS fabrication is an extremely exciting endeavor due to the customized nature of process technologies and the diversity of processing capabilities. MEMS fabrication uses many of the same techniques that are used in the integrated circuit domain such as oxidation, diffusion, ion implantation, etc., and combines these capabilities with highly specialized micromachining processes.Processes such as bulk and surface micromachining as well as high-aspect-ratio micromachining (HARM) selectively remove parts of the silicon or add structural layers to form the mechanical and electromechanical components. While integrated circuits are designed to exploit the electrical properties of silicon, MEMS takes advantage of other material properties like optical, mechanical etc. Within the wider field of MST we also see processes like micro molding, laser ablation etc. used to create microsystems components.

4. History of MEMS

The history of MEMS is useful to illustrate its diversity, challenges and applications. The following chronology summarizes some of the key MEMS milestones.

Table 1: Chronological History of MEMS Technology.

1958	Silicon strain gauges become commercially available.
1961	First silicon pressure sensor demonstrated.
1970	First silicon accelerometer demonstrated.
1979	First micromachined inkjet nozzle.

Early 1980s	First experiments in surface micro machined silicon.
1988	First MEMS conference.
1990s	Novel methods of micromachining developed with an aim of improving sensors.
1993	First surface micro machined accelerometer sold (Analog Devices, ADXL50).
2000s	Massive industrialization and commercialization.
2005	Analog Devices shipped its two hundred millionth MEMS-based inertial sensors.

5. Advantages and Application of MEMS Technology for Space Applications

MEMS Technology has several distinct advantages as a manufacturing technology. In the first place, the interdisciplinary nature of MEMS technology and its micromachining techniques, as well as its diversity of applications has resulted in an unprecedented range of devices and synergies across previously unrelated fields (for example biology and microelectronics). Secondly, MEMS with its batch fabrication techniques enables components and devices to be manufactured with increased performance and reliability, combined with the obvious advantages of reduced physical size, volume, weight and cost. Thirdly, MEMS provides the basis for the manufacture of products that cannot be made by other methods. These factors make MEMS as pervasive technology as integrated circuit microchips.

High volume MEMS can be found in a diversity of applications across multiple markets. In the context of emerging technologies, MEMS products were initially centered around technology-product paradigms rather than product-market paradigms. Consequently, MEMS devices have found numerous applications across a diversity of industries. For example, MEMS accelerometer initially found a launching application in airbag sensors, from this they were further developed to serve other applications in the automotive sector such as Electronic Stability Program (ESP) and rollover detection. Thanks to technological advancements, production costs went down and the sensors became affordable for consumer applications.

There are numerous possible applications for MEMS and Nanotechnology. As a breakthrough technology, allowing unparalleled synergy between previously unrelated fields such as biology and microelectronics, many new MEMS and Nanotechnology applications will emerge, expanding beyond that which is currently identified or known. Some of the few applications of current interest include:

Table 2: Examples of MEMS applications.

Technology/ Sensors	Aerospace, Defense and Automotive Applications
Inertial sensors	Missile guidance, navigation, laser range finder, Airbags, vehicle dynamic control, navigation systems, active suspension, roll detection.

RF MEMS	Switches and tunable capacitors for radar and communications
Pressure sensors	Flight control systems, cabin pressure, hydraulic systems Manifold Air Pressure, Tire Pressure Management Systems
Flow sensors	Air intake of engine, air quality in cabin
IR sensors	Fingerprint sensors for authentication, Security monitoring

6. Conclusion

The reduction of mission costs requires substantial reductions in mass, volume, and power consumption. At the same time,ever-more ambitious science objectives require miniaturization without loss of performance. MEMS enable this explorationof space by producing miniature science and engineering devices that are potentially integral with radiation-hardened electronics.Reliability, packaging and flight qualification of MEMS and their related systems are critical in fast insertion ofthese breakthrough EMS technologies into space applications. The international space and MEMS communities recognizethis, and large efforts are being created to produce an exciting new era in space exploration.

References

[1] Micro-IMU forspace applications," 1998GOMAC andHEART Conference, Arlington, Virginia, March 17-20, 1998.

[2] W.T.Pike,R.D.Martin, W.J.Kaiser, andW.B.Banerdt, “Development ofmicroseismometers forspace applications," Ann. Geophys.,Vol. 14,pp.C828, 1996.

[3] H.R.Shea,“RadiationSensitivityofMEMSDevices”,to appearinJournalofMicro/Nanolithography, MEMS,andMOEMS,2009

[4] Alandry, B. &Latorre, L. &Mailly, F. &Nouet, P. 2010. CMOS-MEMS Inertial Measurement Unit. In: Proceeding of the 2010 IEEE Sensors Conference. Kona, HI, USA. 1.-4.11.2010, pp. 1033-1036.

[5] Ayazi, F. 2011. Multi-DOF Inertial Mems: From Gaming to Dead Reckoning. In: Proceedings of the 16thInternational Solid-State Sensors, Actuators and Microsystems Conference. Beijing, China. 5.-9.6.2011, pp. 2805-2808.

[6] Acar, C. &Shkel, A. M. 2003. Experimental evaluation and comparative analysis of commercial variable-capacitance MEMS accelerometers. Journal of Micromechanics and Microengineering. Vol. 13, issue 5, pp. 634-645.

[7] SeverinWaldis,FredericZamkotsian, Pierre-Andre Clerc, WilfriedNoell,MichaelZickar,PatrickLanzoni,andNicode Rooij,“Uniformtilt-anglemicromirrorarrayfor multiobjectspectroscopy”, J. Micro/Nanolith. MEMS MOEMS7,021014(2008).

[8] R.Maboudianand R.T. Howe, “Critical Review: Adhesion inSurface MicromechanicalStructures," J.Vac. Sci. and Technol. B,Vol. 15,Jan. 1997.

[9] Robert Osiander, M. Ann Garrison Darrin, John L.Champion (Editors), “MEMS and Microstructures inAerospaceApplications”, CRC(2005)400pages,Chapter11,Micropropulsiontechnologies,J.Schein,pp.229

[10] L.P.B.Katehi, G.M.Rebeiz, andC.T.-C. Nuygen, "MEMS and Si-micromachinedComponents forLow-Power, high Frequency Communications Systems," IEEE MTT-S Digest, pp. 331-333, 1998.

[11] H.Helvajian,ed,“MicroengineeringAerospaceSystems”,TheAerospacePress,1999