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WHITE PAPER

Micro-Electro-Mechanical Systems (MEMS): State Of The Technology

Introduction

Micro-electro-mechanical systems (MEMS) is one of the fastest growing and most promising electronics technologies. Using existing integrated circuit chip fabrication processes to manufacture micro-scale embedded electrical, mechanical, and optical systems opens the door to many different commercial and military applications. The military, through the Defense Advanced Research Projects Agency (DARPA), has led the way in developing this technology and bringing it close to mass commercialization. MEMS are already being used in automobile air bag crash sensors, ink jet printers, and NASA's Mars Microprobe. Many military systems are being investigated for their potential for MEMS insertion to realize cost, weight, and performance benefits.

Background

MEMS technology is developed using current microelectronics manufacturing processes and materials to produce embedded, integrated electrical, mechanical, and optical systems all on one integrated circuit. The four basic components of MEMS are microsensors, microactuators, microelectronics, and microstructures. Current technology can produce a single integrated circuit package that has micro-pumps, valves, and switches along with the necessary electronic components to intelligently control them. The goal of MEMS technology is to integrate sensors that merge mechanical, optical, acoustic, and fluidic elements with electronics to create microsystems that can sense, commute, act and communicate [OUSD/A&T Report, Dec 97].

Originally the National Science Foundation (NSF) funded the MEMS research through a few universities. But more recently, DARPA has been the driving force behind MEMS technology development with significantly more funding to many universities. As the technology has matured over the years, industry has become involved and began participating in applied research projects. These applied research projects have led to the development of commercialized products, items such as automobile air bag crash sensors and ink jet printers.

The present market for MEMS is primarily in pressure and inertial sensors and inkjet print heads. The pressure and inertial sensor market is growing, while the fluidic sensors are in their infancy. The current MEMS can sense, but having them physically act (actuators) based on the sensing is not heavily commercialized to date.

The following is a list of military applications that are currently being investigated:

- Inertial systems for munitions guidance

- Unattended, low power, wireless sensors
- Weapons safing, arming, and fuzing
- Mass data storage devices
- Condition-based maintenance
- Chemical/Biological agent detection
- Aircraft aerodynamic control
- Engine and propulsion control

MEMS technology is extremely important to the military. MEMS is being investigated for its insertion into legacy system applications as well as new applications. The potential for cost and weight reductions and performance improvements is significant. Comparison of a standard inertial measurement unit (IMU) with a MEMS unit:

	Conventional	MEMS
Mass	1587.5 grams	10 grams
Size	15 cm x 8 cm x 5 cm	2 cm x 2 cm x 0.5 cm
Power	35 W	~ 1 mw
Survivability	35 g's	100,000 g's
Cost	$20K	$500

The automobile industry realized the cost, weight and performance value in implementing MEMS accelerometers in air bag crash systems. The auto industry replaced a conventional $50 sensor and control system with a $5 MEMS version of an integrated sensor and control system that had better performance and higher reliability.

Crane's Role

Currently, Crane is performing contract management for a DARPA project that contains MEMS investigations as a part of the research. Crane will develop a test plan and conduct testing on the MEMS accelerometers, and develop a paper that can be presented at a variety of MEMS conferences.

Crane is also trying to 1) identify MEMS problems that need addressed, 2) identify funds for additional commercial MEMS component procurement and test labor to evaluate the problems, and 3) identify and evaluate potential military applications. The testing and report generation on problem and opportunity areas of MEMS is key to building Crane's credibility within the MEMS community.

Crane participated in the kick-off meeting of the Indiana Microsystems Commercialization Consortium in February 2001. This consortium is a group of industry, government, and academia whose purpose is to identify and commercialize MEMS technology applications. The first commercial application brought to the consortium is a Honeywell aircraft landing gear sensor system.

Crane is ramping up in MEMS knowledge and expertise for two reasons:

1) MEMS is recognized as a large growth area in military microelectronics based systems
2) Microelectronics is a Crane Core Equity

Crane's role is to provide customers expertise in engineering analysis and testing of MEMS related to packaging, performance, and application suitability. Crane will provide engineering and test services to customers with MEMS applications. Crane will leverage off our existing microelectronics packaging expertise to address MEMS packaging, which is one of the most prominent problems with MEMS.

Issues & Concerns

- Identifying potential on-center customers that can provide the seed funding for developing this Crane capability.

- Development of the MEMS technologist.

- "Breaking in" to the MEMS arena with something substantial to offer.

Informational References

Special Technology Area Review On Micro-Opto-Electro-Mechanical-Systems, Office of the Under Secretary of Defense (Acquisition and Technology), December 1997.

Microelectromechanical Systems Opportunities, Department of Defense, December 1995.

Maluf, Nadim. *An Introduction to Microelectromechanical Systems Engineering.* Artech House. 2000.

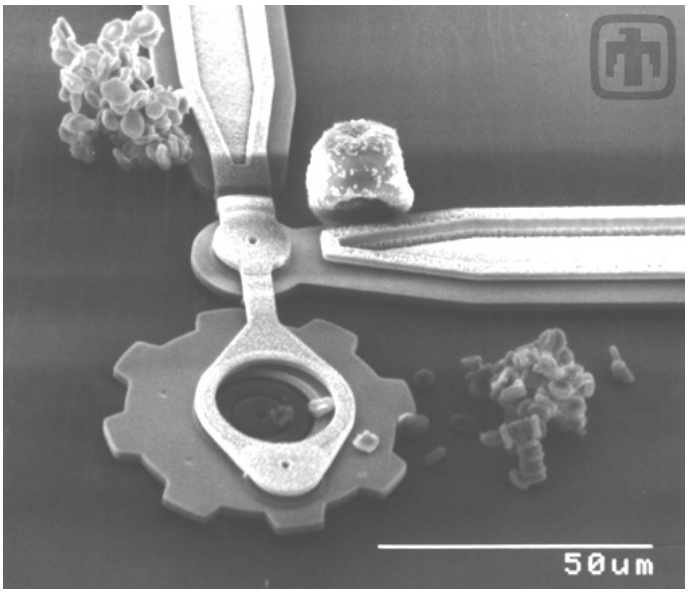
http://web-ext2.darpa.mil/MTO/MEMS/index.html

http://www.mdl.sandia.gov/Micromachine/

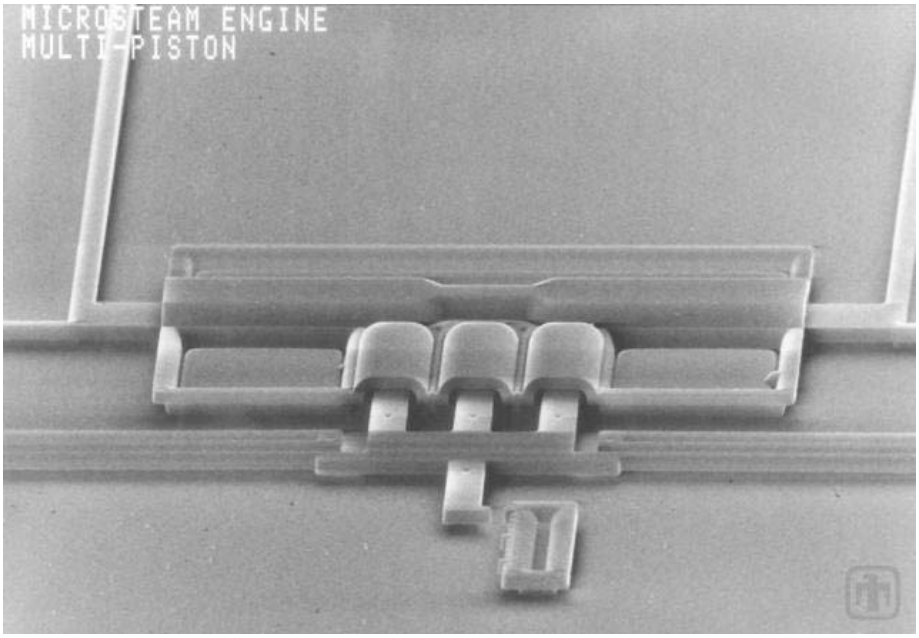
http://www.ida.org/mems/

http://mems.isi.edu

Images



Gear Assembly. Note the single grain of pollen (right) and the two lumps of coagulated red blood cells (upper left & lower right).



3 cylinder steam engine. The width of the engine is less than the width of a human hair.