Background

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MEMS in the Pittsburgh Region

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Micro-electromechanical systems (MEMS) is a technology that combines computing abilities with tiny mechanical devices such as sensors, valves, gears, mirrors, and actuators embedded in semiconductor chips. The integrated circuits provide the “thinking” part of the device, while other components complement this intelligence with active control and perception. It is expected to be a foundational technology of the next decade, particularly as it is applied in the aerospace and life sciences industries.

MEMS do three things; first, a sensor detects a non-electrical force, such as pressure, motion, airflow, heat, sound, magnetism or any other force. Second, a transducer converts those forces into electrical signals. Finally, in response to those electrical signals an actuator performs a mechanical

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action. The configuration of sensors and desired outcomes or actions are limited only by the imagination and innovation on the part of MEMS designers and manufacturers.

MEMS deals with a scale that is measured in millionths of an inch, and products that contain MEMS harness the existing micro-scale fabrication capabilities and resources of semiconductor processing to produce electro-mechanical devices. Microelectromechanical systems were first developed in the mid-1980s as a way to introduce new functionality to semiconductors, which represent integrated electronic circuitry on a silicon chip.

With MEMS technology, chips are etched and layered with microscopic structure that adds mechanical capabilities. But MEMS also is distinguishable due to the use of micro-machines that contain gears, valves and other parts. As such, MEMS is much more than the miniaturization of components. It is the marriage of microscopic electronics and microscopic mechanics.

By 2012, MEMS makers will be shipping 8.1 billion units a year worth a total of $15.5 billion, and nearly half that market will be consumer devices.

Some of the earliest MEMS patents originated in Pittsburgh. For about a decade beginning in 1965, Dr. Harvey Nathanson, in conjunction with Robert Wickstrom, Dr. William Newell and a team of 18 engineers, scientists and technicians at the Westinghouse Research Labs in Pittsburgh, developed a number of silicon- friendly MEMS devices, including vibrating beam MEMS, microwave relay and contact MEMS, field emission MEMS, accelerometer MEMS and TV Projection MEMS.

Although most people may not realize it, MEMS is part of everyday life. Most video projectors contain a MEMS device, as do high-end televisions. The print head in ink jet printers is a MEMS device, and automobile airbags and vehicle stability sensors depend on MEMS. The technology is revolutionizing biomedicine, consumer electronics and telecommunications, such as cell phones and other wireless mobile communications devices, but at the same time it is “evolutionizing” products, making them better, faster, smarter and more effective.

Cell phones feature improved performance with MEMS-enabled speakers, microphones and microphone arrays integrated with signal processing on a single chip. MEMS-enabled projection devices, already in public theaters, boast one million microscopic mirrors. Medical diagnostics now apply MEMS devices to enable onsite diagnostic testing greatly reducing the need for lab analysis.

In short, because MEMS is an enabling technology that allows other devices do more things faster and cheaper, there are as many applications for MEMS as there are for semiconductors.

MEMS Industry Group

Southwestern Pennsylvania is fortunate to be the home of the MEMS Industry Group (MIG), ensuring continued development of MEMS and nanotechnology in the region.

Launched in January 2001 with the help of Carnegie Mellon University professor Ken Gabriel, referred to as the architect of the MEMS industry by *Forbes* magazine, MIG began as the premier trade association of the North American MEMS and microstructures industries, but now includes a number of international members. It has nearly 75 international member companies nationwide, including GE Global Research, Honeywell, Intel, Northrop Grumman, Texas Instruments and Pittsburgh-based Akustica and XACTIX.

MIG's mission is to:

- enable the exchange of non-proprietary information among members
- provide reliable industry data that furthers the development of technology
- work with various groups to bring about the greater commercial development and use of MEMS and MEMS-enabled products

The industry group provides its members with benefits and information previously unavailable to the industry. In addition to an annual industry report published by MIG, members are given access to the latest MIG-generated research, as well as statistics on employment, revenue and markets. In this way, MIG strives to be the unifying voice of the commercial MEMS industry.

While at the Defense Advanced Research Projects Agency (DARPA), Gabriel created a funding program to foster greater development of MEMS for commercial and defense applications. MEMS-related research is still funded by DARPA today.

MIG hosts two conferences focusing on the greater commercialization of MEMS technology. Each spring, MIG hosts its annual meeting, called the MEMS Technology Roadmap and Industry Congress (METRIC). The METRIC annual meeting is a members-only event which brings together MEMS experts and industry leaders to discuss critical issues related to MEMS commercialization and manufacturability. However, METRIC is not a typical conference. Seven months in advance of the conference, MIG organizes topic-specific working groups, made up of MEMS industry professionals, to address issues affecting the commercialization of MEMS technology.

At METRIC, these working groups meet in person to formulate recommendations and conclusions, based upon months of primary and secondary research conducted by MIG. Past METRIC conferences have dealt with issues related to mapping the next five to 20 years in MEMS technology development, MEMS foundries and fabrication, MEMS reliability, accelerated lifetime testing, technical and scientific challenges to successful MEMS commercialization and most recently, MEMS integration issues.

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Based on the research at METRIC, MIG has authored several industry reports focused on the topics of each conference. In its 2008 - 2009 report, MIG focused on China, Europe and other global markets. The report concludes that in spite of a continued sales decline that was caused by a depressed automobile industry, a bright spot will be consumer electronic applications.

In addition to the annual METRIC conference, MIG hosts a one-day, executive-level conference focused on the customer-side of MEMS commercialization. In November 2009, MIG will host its fifth annual MEMS Executive Congress in Sonoma, California which in past years ahs been attended by more than 125 executives from around the world.

Regional Companies

Using specific industry classifications within the MEMS cluster, there is an innovative core of related small firms that may share labor pools, technology and markets. They include Akustica, Xactix, Verimetra, Bridge Semiconductors, IC Mechanics and others.

With MIG as its spearhead, southwestern Pennsylvania's cluster of MEMS start-ups may well be key players in new MEMS growth in the United States. Two MEMS companies are located in the same facility on Pittsburgh's south side, furnishing the sector with an attractive hub and exceptional opportunities for resource sharing.

Among Pittsburgh's MEMS companies is XACTIX, which leverages its unique combination of expertise in instrument and equipment design, semiconductor materials processing, micro machining and fabrication and MEMS manufacturing to design and build leading-edge MEMS process equipment. XACTIX is the manufacturer of the Xetch® xenon difluoride (XeF2) etching systems, the X3 Series™ for commercial customers and the e1 Series™ for university customers. These dry isotropic etching tools are popular in the MEMS community due to high selectivity to silicon versus many standard films, including photoresist, silicon dioxide, silicon nitride and aluminum. The Xetch® systems are particularly well suited for release, but are certainly not limited to MEMS applications and are useful where highly selective isotropic silicon etching is required.

In April of 2003, Gabriel's own start-up company, Akustica, Inc., successfully produced the world's first acoustic system on a chip to revolutionize the performance of next-generation hearing aids, cell phones and other acoustic devices. Akustica's system-on-chip solutions are built on a revolutionary platform known as Sensory Silicon™ that combines the functionality of microphones with microelectronics and software onto a single chip. Akustica microphone chips will suppress background noise and be directional and selective. Speaker chips will reproduce sound with greater fidelity, and, with the added ability to detect motion, pressure or proximity, future Akustica chips will enable a wide range of end products to interact more intuitively with users. The company uses a MEMS technology licensed exclusively from Carnegie Mellon University that can be mass-produced at relatively low cost, even by traditional suppliers.

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In February of 2006, Akustica introduced the first single-chip microphone on the market. This small, thin device is designed to replace the Electret Condenser Microphone (ECM), a 50-year old technology that has been used in billions of portable electronic devices while remaining fundamentally unchanged. Akustica's microphone chips are not prone to the same degree of noise that ECMs suffer, and their small size and surface-mountable design make them ideally suited for small consumer electronic devices that are manufactured in high volumes.

As industry analysts that closely follow this market, Yole Development, forecasts in the silicon microphone market to reach $800 million by 2010.

Similarly, IC Mechanics aims to bring price points down in the manufacturing process for all MEMS technologies. The company has pioneered low-temperature processing for its wafers, an improvement over the traditional process, and it has been working to develop MEMS sensors for desktop and laptop computer disk drives, in order to increase and improve sensitivities to vibrations and shock.

In October of 2006, Virtus Advanced Sensors, a developer of MEMS sensors, announced plans to locate its headquarters in Pittsburgh. The company plans to commercialize its sensor technology, which can be used in the automotive industry, as well as medical devices, robotics, consumer electronics, aerospace and defense.

New Developments

Carnegie Mellon researchers found that MEMS memory could put an entire computer system on a chip. The discovery was a result of a research grant by NASA to pursue the design of integrated MEMS storage devices for satellites. Ultimately MEMS-based storage offers faster access times at lower costs than existing disk-drive technology.

MEMS-based storage devices will go into use where portability, high data density, low power consumption and ruggedness are priorities.

Positioned for Growth

Much of the growth in MEMS will be led by applications in medicine, telecommunications and consumer electronics. The industry is estimated to spend approximately $100 million in research and development each year.

In Pittsburgh, no one is better positioned to take advantage of federal investment than the University of Pittsburgh and Carnegie Mellon University, both of which feature MEMS labs.

Carnegie Mellon's Center for Silicon System Implementation is focused on all aspects of integrated system design and manufacturing that spans from network-on-a chip architectures to self-adaptable analog and digital circuits, to ultra low-power nano devices, bio chips and the CAD methodologies that enable them. The Center's 18 faculty researchers span several Carnegie Mellon departments that include electrical and computer engineering, computer science and mechanical engineering.

Together with the university's Institute for Complex Engineered Systems, the facilities at Carnegie Mellon are regarded as one of the best for MEMS development in the U.S.

Through DARPA, local entrepreneurs also can participate in resource sharing at Carnegie Mellon, which can cut the costs of prototyping dramatically. This is because Carnegie Mellon's MEMS facilities support an approach to prototyping that utilizes standard semiconductor technology and post-processing to reduce costs of MEMS production.

In order to foster research in the next generation of MEMS technology, the School of Engineering at the University of Pittsburgh has developed the John A. Swanson Micro and Nanotechnology Laboratory, a premier research laboratory devoted to the fabrication and testing of micro and nano scale systems. The facility was developed to be used by researchers from all engineering departments from across the university, including medicine, chemistry, physics and biology, as well as from local industry. The lab contains photolithographic thin film deposition and removal, in addition to analysis equipment to enable the fabrication and testing of a wide variety of MEMS devices.

Current areas of research include microfluidics, sensors and actuators, acoustics, smart materials, micro chemical reactors, radio frequency identification and communications, materials, microelectromechanical systems design and modeling and bioengineering.

As a result of these initiatives, MEMS talent appears to be moving steadily to the Pittsburgh region. These resources and talent provide good reason to predict that the regional MEMS cluster may rapidly be gaining in size.

Visit:

www.memsindustrygroup.org

www.akustica.com

www.xactix.com

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