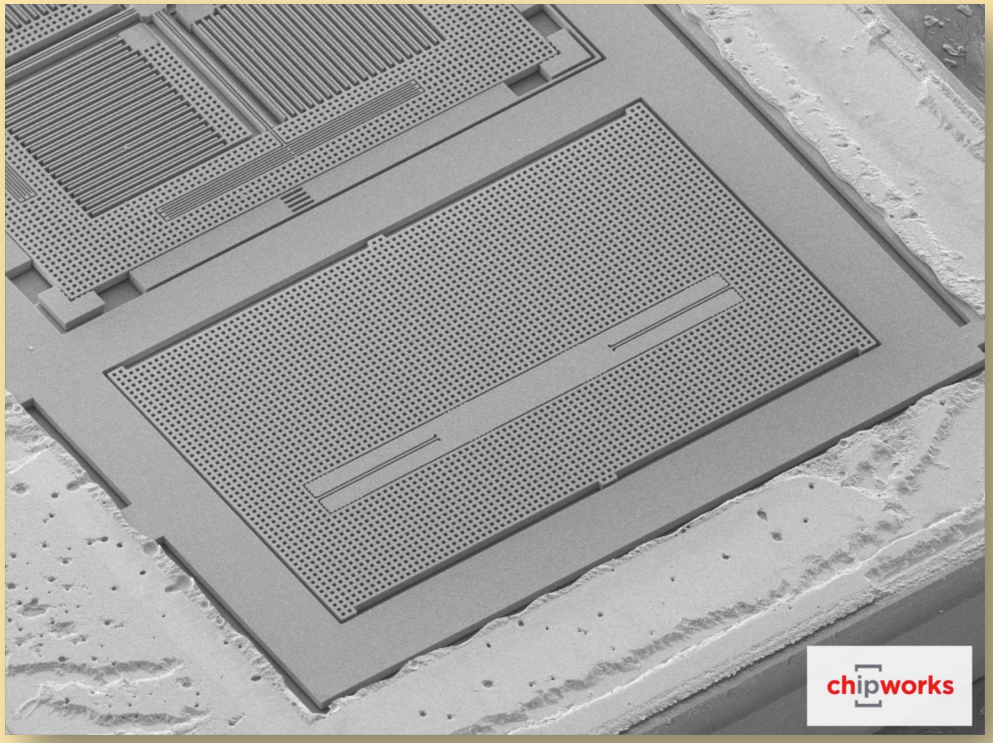
MEMS APPLICATIONS OVERVIEW



3-D accelerometer (inertia sensor) – x & y axes upper left, z axis center
[Image courtesy of ChipWorks]

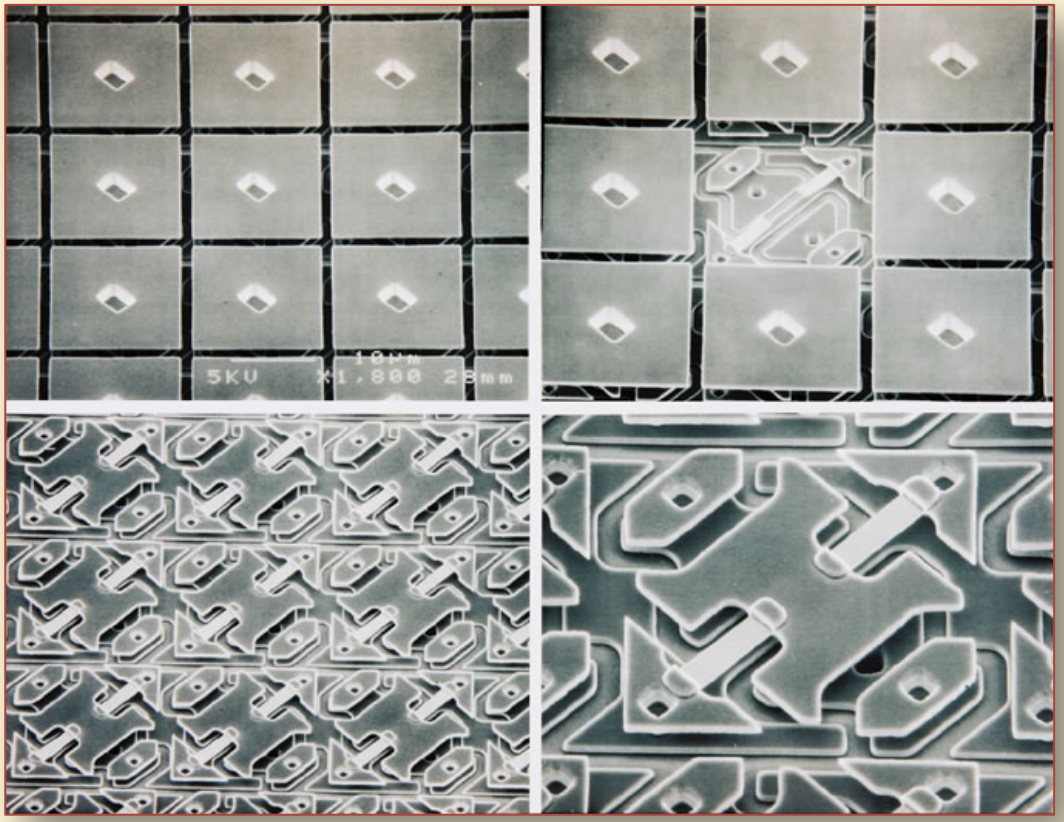
Unit Overview

Microelectromechanical systems (MEMS) are very small devices or groups of devices that can integrate both mechanical and electrical components.

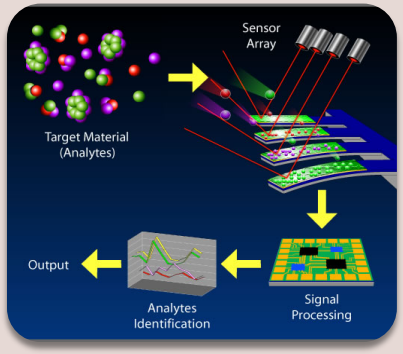
This unit provides a brief summary of MEMS devices already on the market, the various fields in which MEMS are used, and the possibilities for MEMS in these fields.

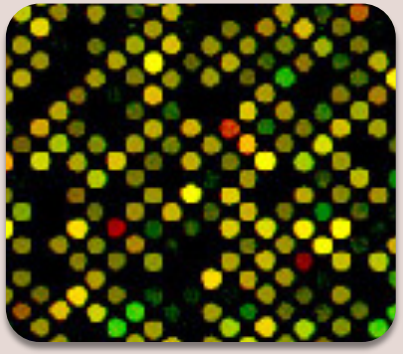
What are MEMS?

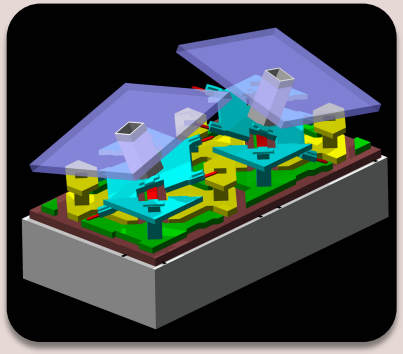
- Micro-Electro-Mechanical-System
- Electronic and mechanical components constructed on one chip or device.
- Milli, micro and nano-size components
- Example – Digital Mirror Devices used for digital light processing.



What do MEMS do?







Sense

- Movement
- Vibration
- Pressure
- Light
- Temperature
- Mass

Think

- Collect information
- Analyze data
- Interpret data
- Make decisions
- React to change

Communicate

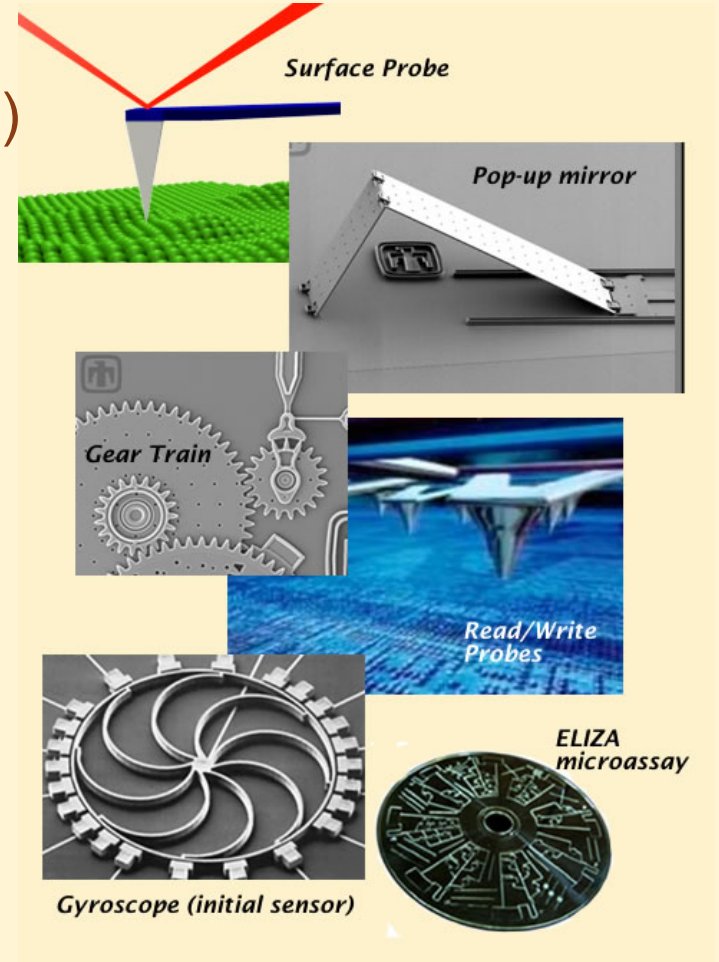
- Send information
- Provide outputs
- Transmit data
- Provide warnings

Act

- Respond to changes
- Move devices
- Transmit light and fluids
- Transport particles

Types of MEMS Devices

- Pressure sensors
- Accelerometers (inertial sensors)
- Micromirrors
- Gear Trains
- Miniature robots
- Fluid pumps
- Microdroplet generators
- Optical scanners
- Probes (neural, surface)
- Analyzers
- Imagers



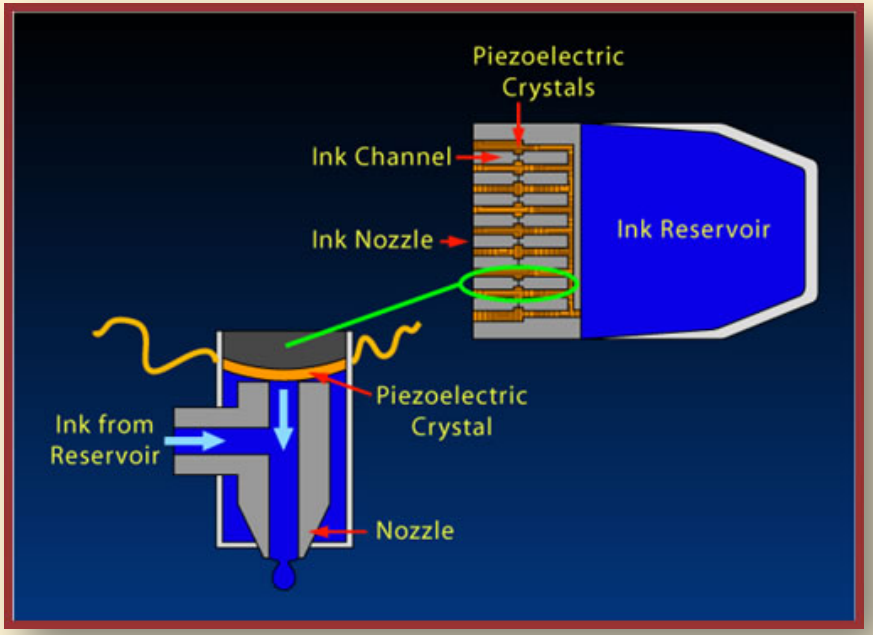
Applications of MEMS

Applications are developed where miniaturization is beneficial:

- Consumer products
- Aerospace
- Automotive
- Biomedical
- Chemical
- Optical displays
- Wireless and optical communications
- Fluidics

Specific Applications of MEMS

- MEMS nozzles and pumps for inkjet printers
- RF devices – Switches, phase shifter resonators, filters and variable antennas
- Fuel delivery systems that can control propellant motion
- Coating sensors that compensate for coating problems (adhesion, surface tension)

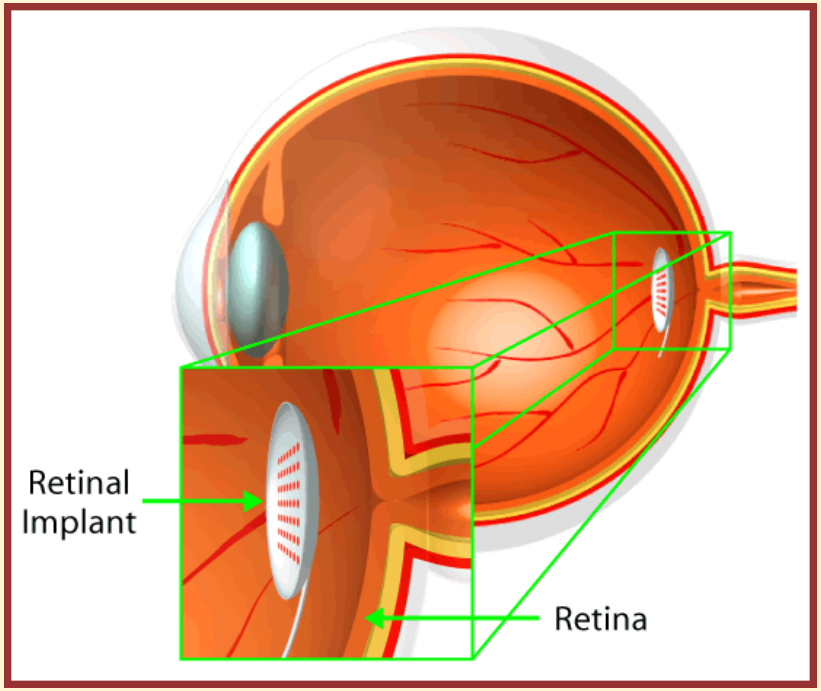


MEMS-based InkJet Printhead
Piezoelectric or bubble jet based injection methods meeting the demand for higher and better resolution printing (smaller droplets). The graphic below illustrates a piezoelectric printhead. When a voltage is applied across the piezoelectric crystal, a minute amount of ink is released into the nozzle.

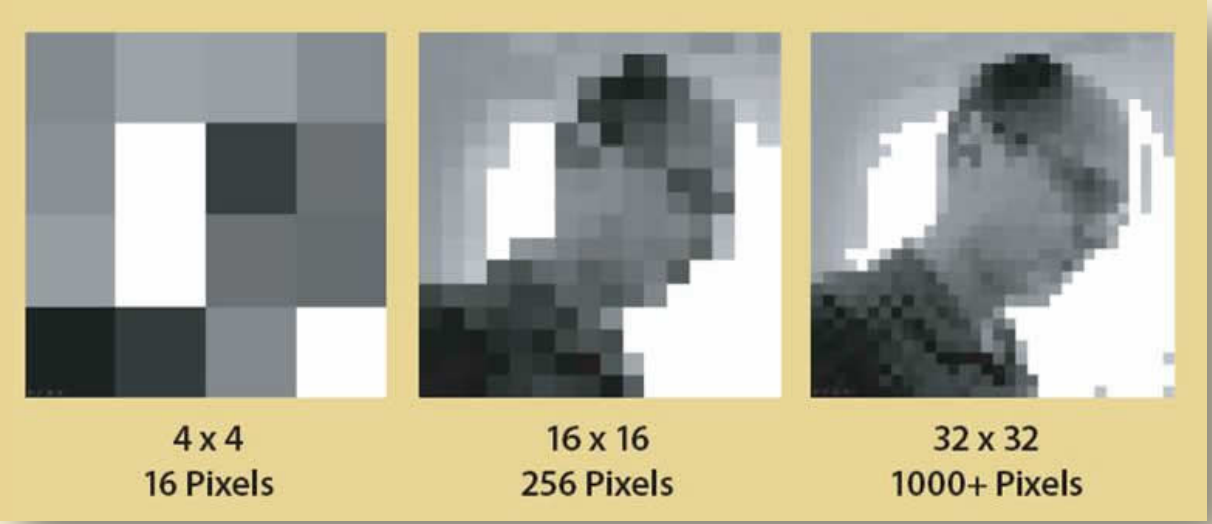
Retinal Prosthesis

- Medical MEMS – aka BioMEMS - can consist of in vivo (internal) components and in vitro (external) components such as this retinal prosthesis
- A microarray or retinal implant is implanted in vivo on the retina.
- An external camera and processor are mounted in a pair of glasses.
- Watch this video to see how it works.

https://youtu.be/Bi_HpbFKnSw



Retinal Prosthesis: What the patient sees



Images generated by the DOE-funded Artificial Retinal Implant Vision Simulator devised and developed by Dr. Wolfgang Fink and Mark Tarbell at the Visual and Autonomous Exploration Systems Research Laboratory, California Institute of Technology.
[Printed with permission.]

These images show what a patient with a MEMS retinal prosthesis should see. Increasing the number of electrodes in the retina array results in more visual perceptions and higher resolution vision.

MEMS Sensors

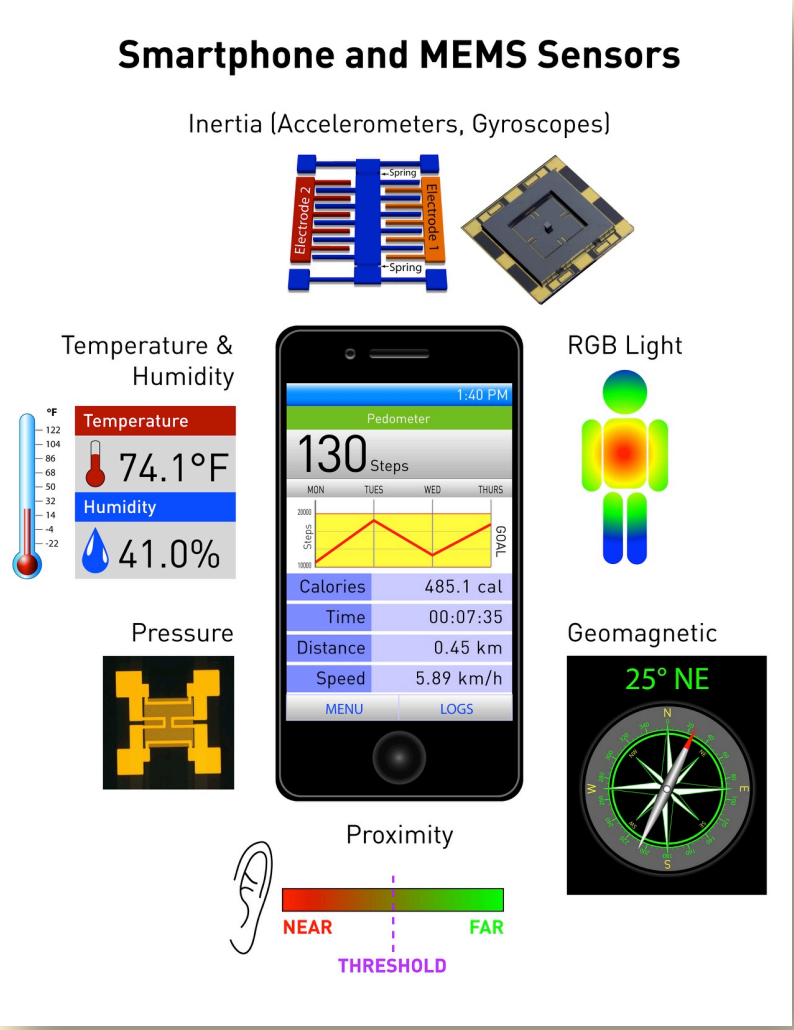
Sensors are a major application for MEMS devices.

Three primary MEMS sensors

- pressure sensors
- chemical sensors
- inertial sensors (accelerometers, gyroscopes)

MEMS sensors can be used in combinations with other sensors for multisensing applications. For example, a MEMS can be designed with sensors to measure the flow rate of a liquid sample and at the same time identify any contaminates within the sample.

Smartphones and MEMS

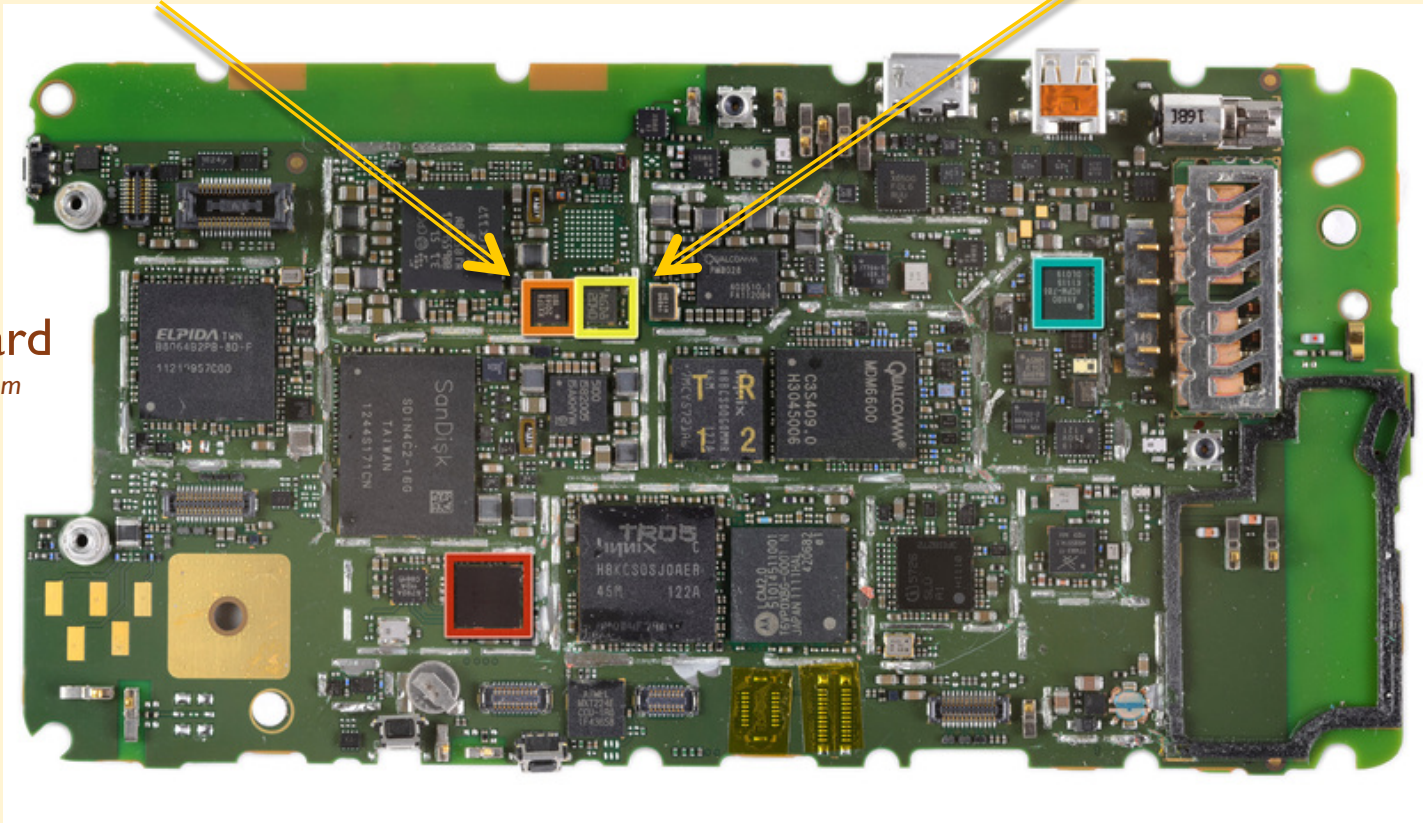


Smartphones can do much of what they do because of the various MEMS sensors built into them.

- Inertial
- Pressure
- RGB
- Geomagnetic
- Temperature
- Humidity
- Proximity
- To name a few

Smartphones, Tablets, Laptops, Cameras

They all have MEMS inertial sensors (gyroscopes and accelerometers) as well as PS, transmitters/receivers.



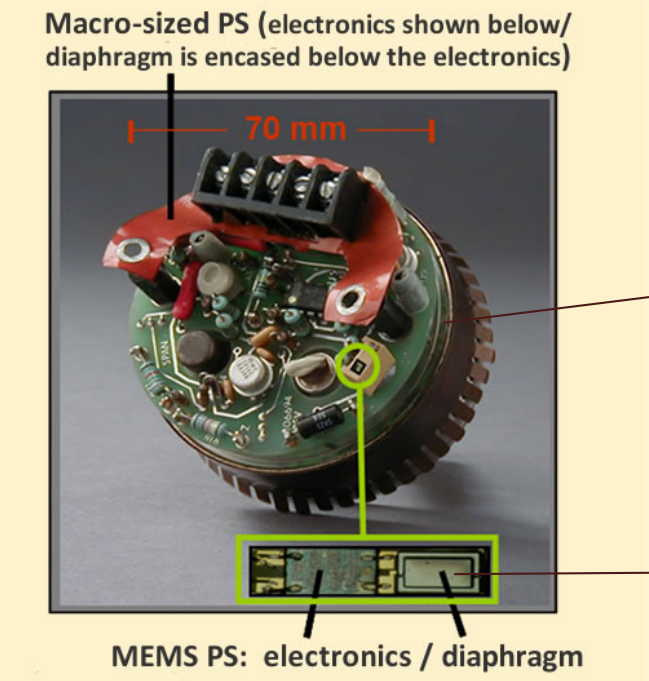
Droid Card

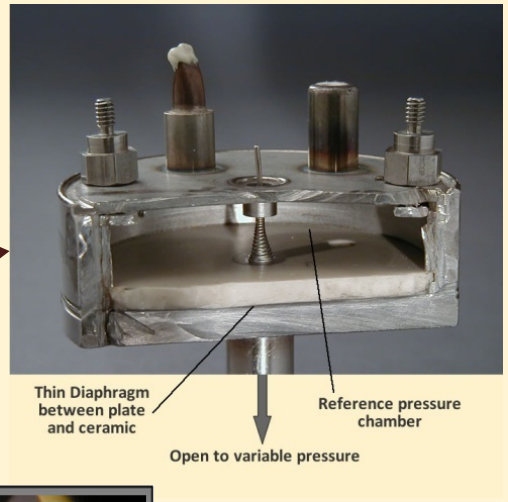
Courtesy of ifixit.com

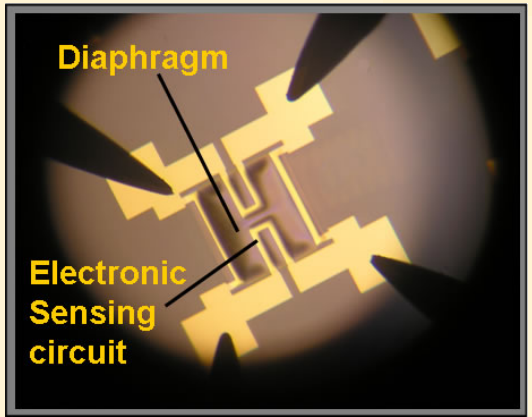
http://www.ifixit.com/Teardown/Motorola-Droid-Bionic-Teardown/6449/1

MEMS Scale – Pressure Sensors (PS)

A pressure sensor is a device consisting of a mechanical component (diaphragm) and electronic components. These pictures compare a macro-size pressure sensor (70mm in diameter) to a MEMS pressure sensor



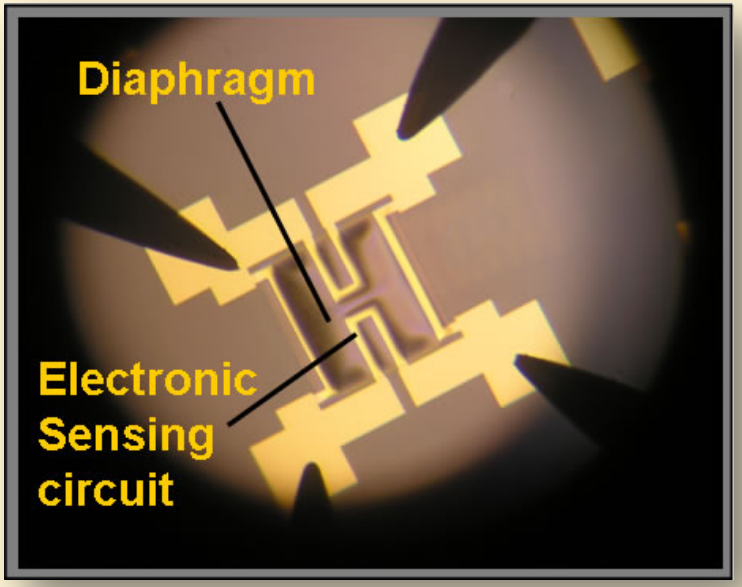




[Macro PS photos courtesy of Bob Willis
MEMS diaphragm courtesy of UNM/MTTC]

MEMS Pressure Sensor

- MEMS pressure sensors use a flexible diaphragm as the sensing device.
- One side of the diaphragm is exposed to a sealed, reference pressure and the other side is open to external pressure.
- The diaphragm moves with a change in the external pressure.



MEMS Pressure Sensor
[Courtesy of the MTTC, University of New Mexico]

What are some possible applications for this type of sensor?

MEMS in the Automotive Industry

MEMS pressure sensors sense, monitor and transmit

- Tire pressure
- Fuel pressure
- Oil pressure
- Air flow
- Absolute air pressure within the intake manifold of the engine

Pressure Sensors in BioMedical Applications

- Blood PS
- Intracranial PS
- PS in endoscopes
- Sensors for infusion pumps

RF (radio frequency) elements incorporated into the MEMS device allow the sensor to transmit its measurements to an external receiver.

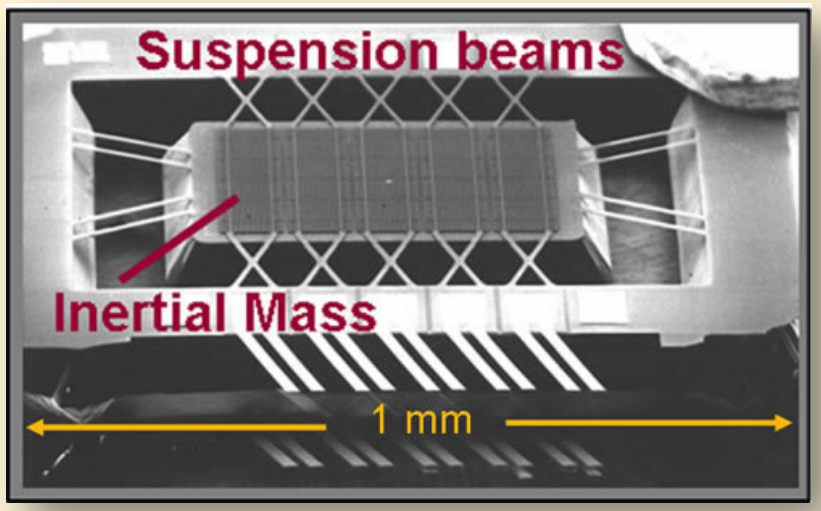
MEMS Inertial Sensors

Newton's First Law of Motion

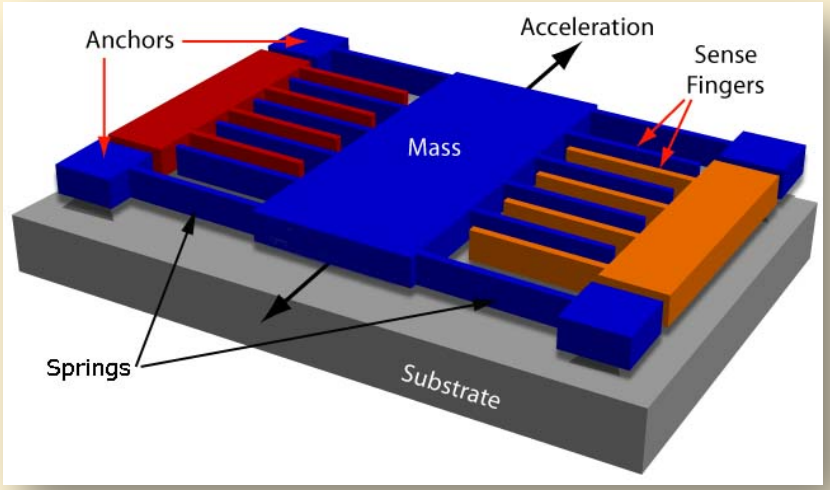
"An object at rest tends to stay at rest and an object in motion tends to stay in motion with the same speed and in the same direction unless acted upon by an unbalanced force."

MEMS inertial sensors are designed to sense a change in an object's inertia, and then convert, or transduce inertial force into a measurable signal

MEMS Accelerometers



MEMS out-of-plane Accelerometer
[Photo courtesy of Khalil Najafi, University of Michigan]

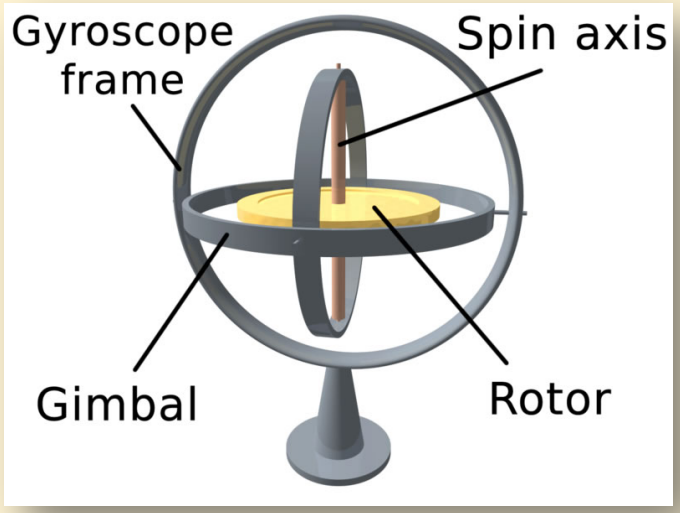


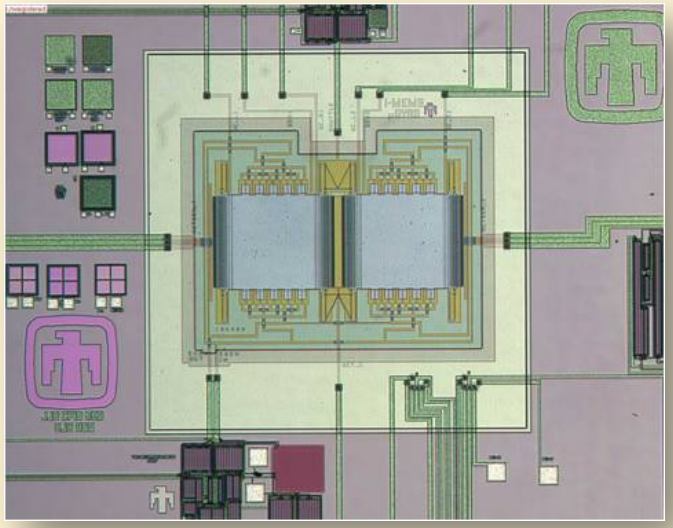
MEMS In-plane accelerometer

The simplest MEMS accelerometer sensor is an inertial mass suspended by springs. The mass is deflected from its nominal position as a result of acceleration. This deflection of the mass is converted to an electrical signal as the sensor's output.

MEMS Gyroscopes

A gyroscope is generally a spinning wheel or disk with a free axis allowing it to take any orientation *(below left)*. Some MEMS gyroscopes use a vibrating structure rather than the traditional rotating disk to determine orientation *(see bottom right)*.

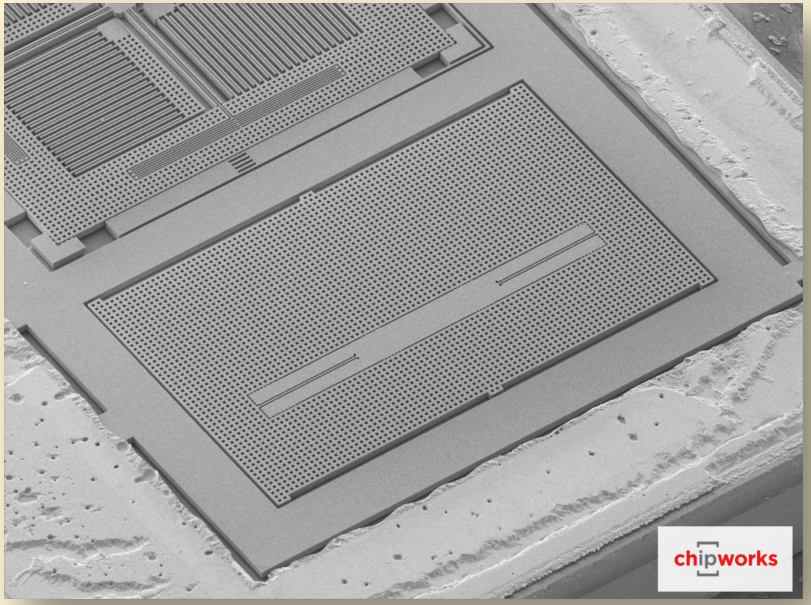




MEMS Vibrating Ring Gyroscope
[(Photo courtesy of Sandia National Laboratories]

MEMS Inertial Sensors in Automobiles

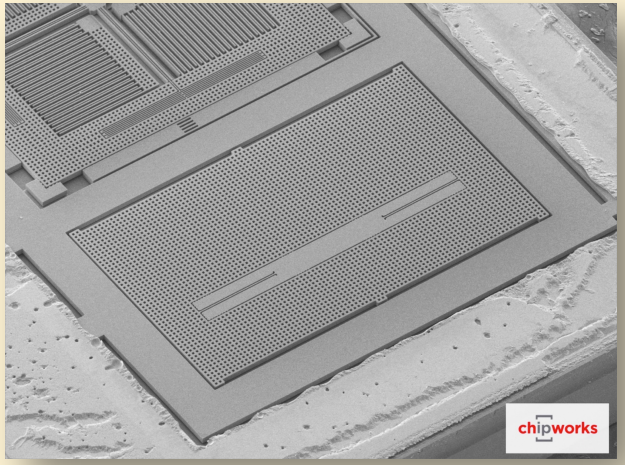
- Airbag deployment
- "Smart" sensors for collision avoidance and skid detection
- Active suspension
- Automobile navigation
- Antitheft system
- Headlight leveling and positioning
- Rollover detectors

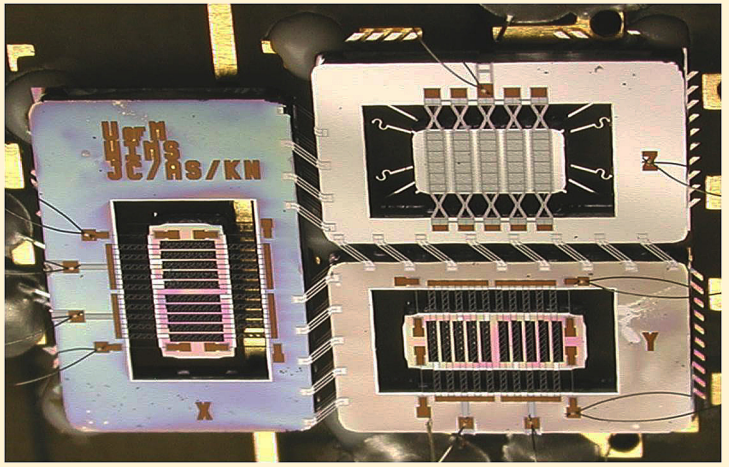


3-axis High-Performance Micromachined Accelerometer
(Each accelerometer senses movement in one direction. The top 2 "in-plane" accelerometers sense x & y directions. The "out-of-plane" accelerometer on the bottom sense movement in the z direction.)
[Image courtesy of Chipworks]

Other Applications of MEMS Inertial Sensors

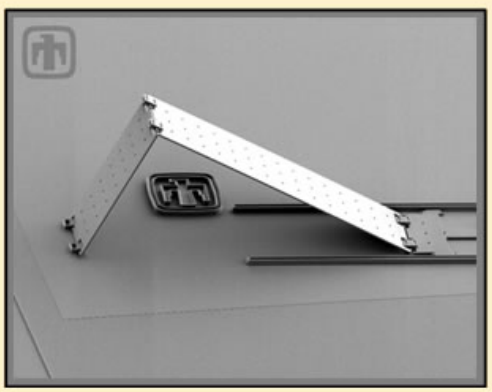
- Motion and shock detection
- Vibration detection and measurement
- Measurement of tilt and inclination
- Anti-theft devices
- Home security devices
- Computer screen scrolling and zooming devices
- Gaming devices for portables and PC's (e.g. Wii and Playstation)
- Image stabilizer cameras and phones



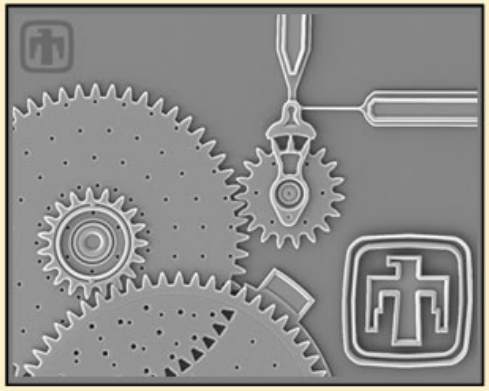


Comparison of 3-axis accelerometers – new technology (top), old technology (bottom)]

Other Types of MEMS



Mirror (popped-up)



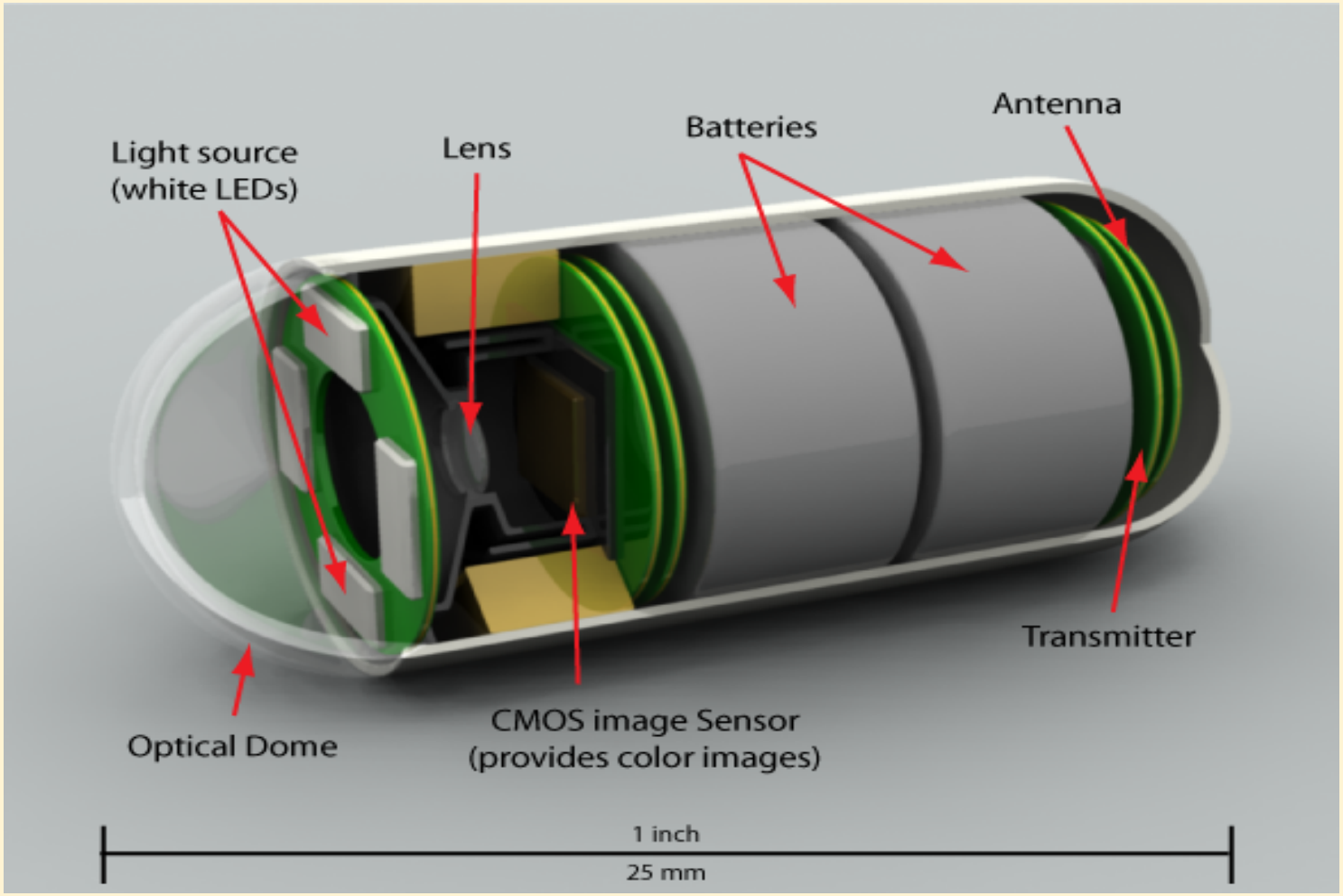
Gear Train

Courtesy of Sandia National Laboratories
SUMMiT™ Technologies, www.mems.sandia.gov

In addition to sensors, MEMS consist of pumping devices, gear trains, moveable mirrors, miniature robots, tweezers, tools, lens, and lasers.

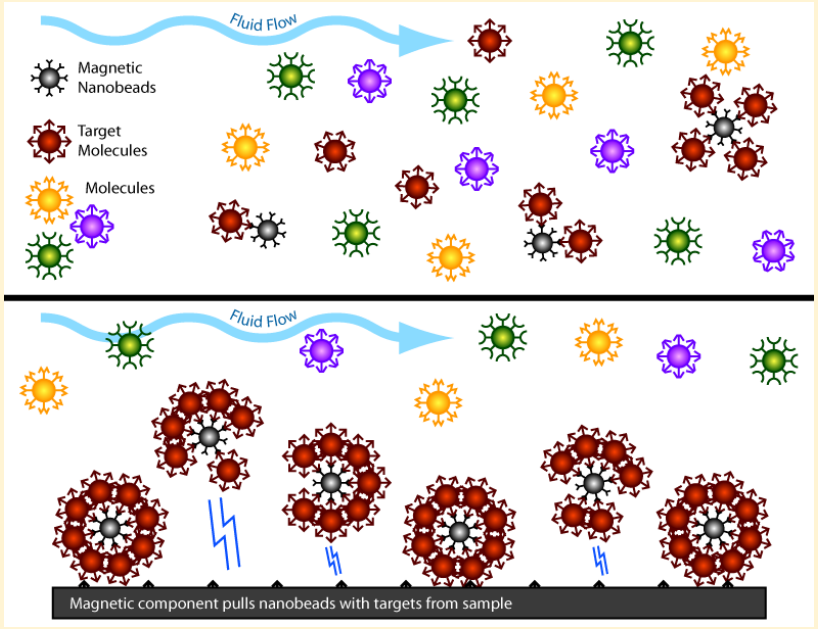
These devices have found numerous applications with various fields such as biomedical, optical, wireless networks, aerospace, and consumer products.

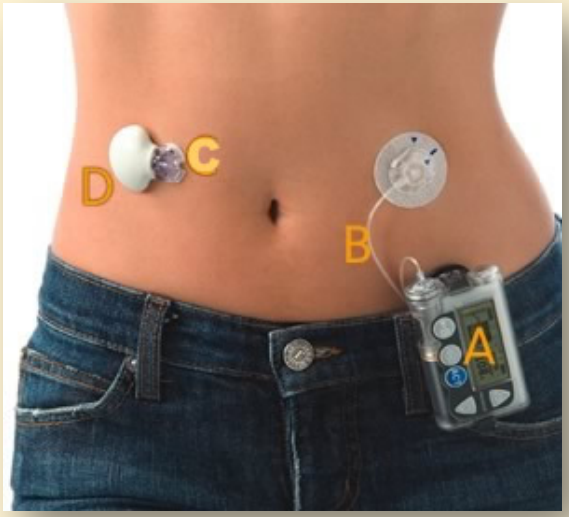
Pill Cam for Diagnostic Applications



MEMS in the Medical Field

- Drug delivery systems.
- Glucose monitors (chemical sensor)
- Clinical Lab Sample Analysis





MiniMed Paradigm[R] 522 insulin pump, with MiniLinkTM] transmitter and infusion set. A chemical sensor (C) measures the blood glucose and a transmitter (D) that sends the measurement to the a computer in (A). (A) also contains a micropump that delivers a precise amount of insulin through the cannula (B) to the patient. This is a continuous bioMEMS monitoring and drug delivery system.
(Printed with permission from Medtronic Diabetes)

Clinical Laboratory Testing

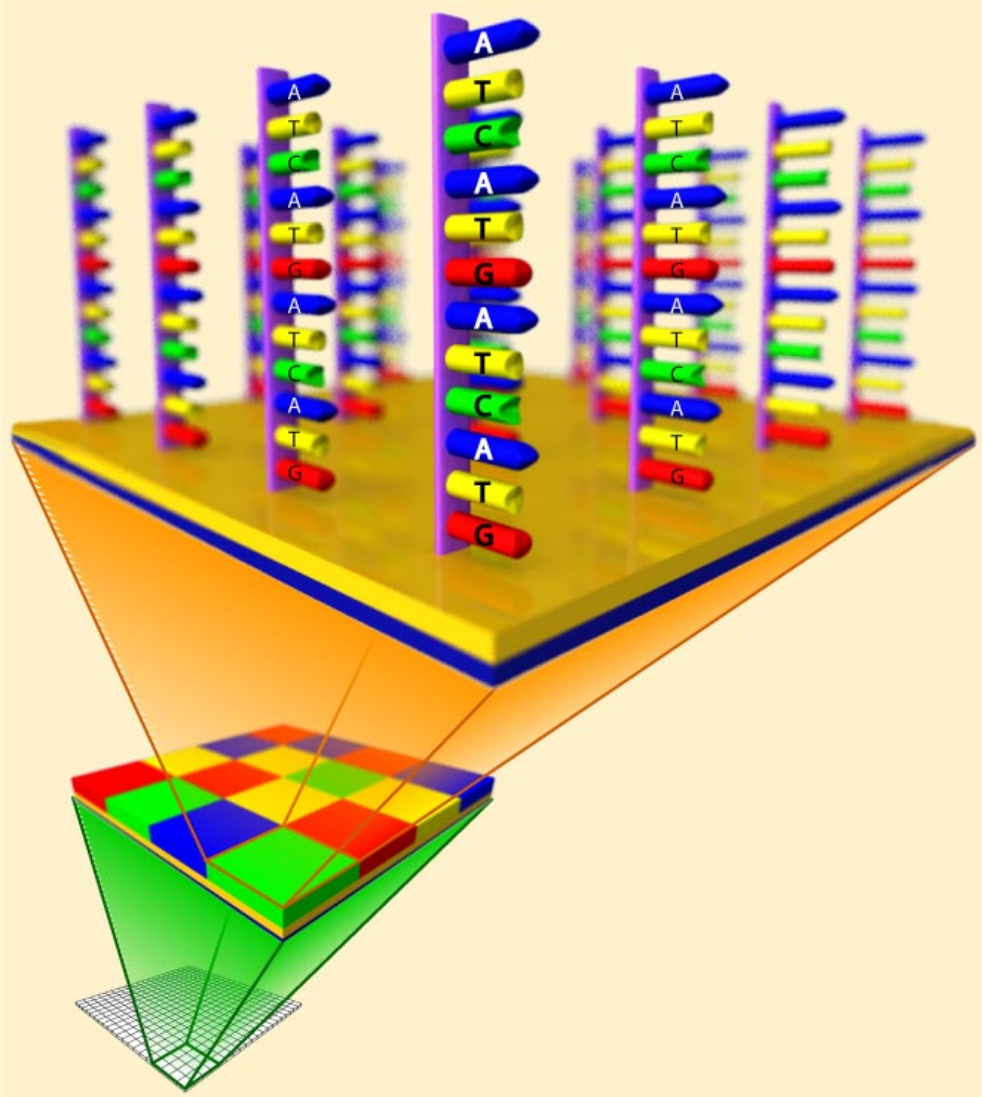
A lab-on-a-chip (LOC) takes the laboratory testing of biomolecular samples (e.g. blood, urine, sweat, sputum) out of the clinical lab and places it in the field or point-of-care (POC).

LOCs use microfluidics and chemical sensors to simultaneously identify multiples analytes (substances being analyzed).

Lab-on-a-chip (LOC)

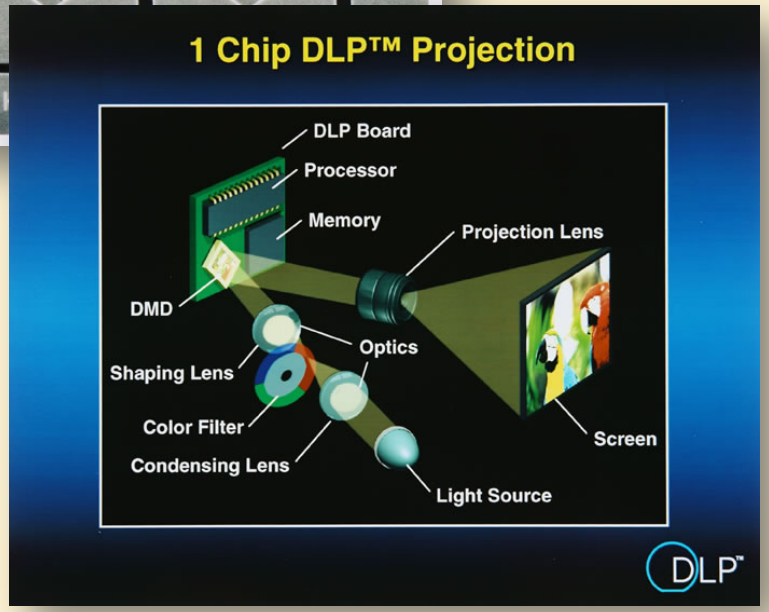
DNA Microarrays

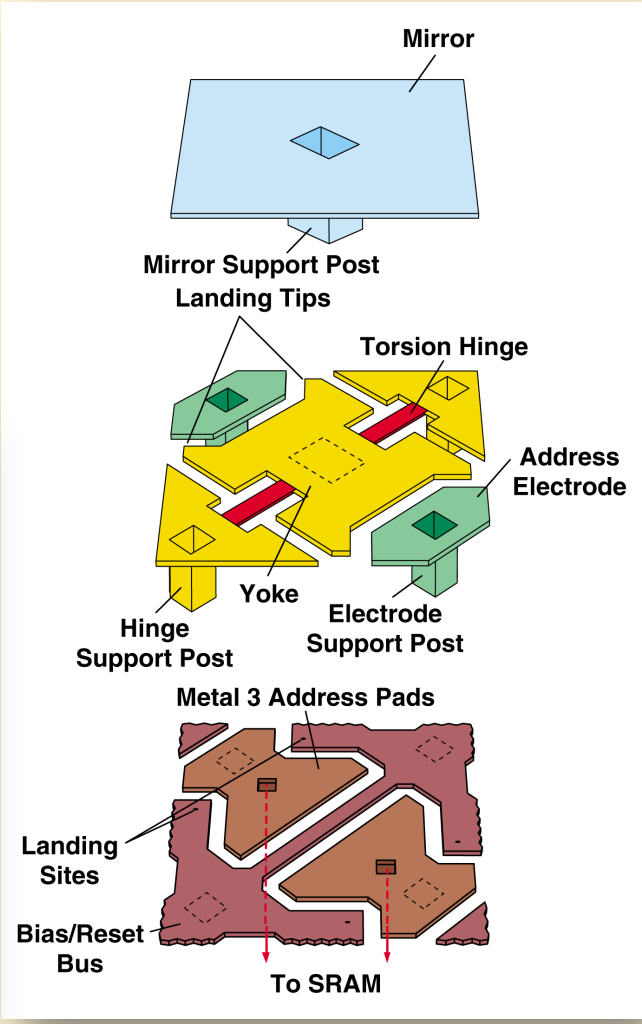
Genetic testing
and comparison



Optical MEMS – The Digital Mirror Device (DMD)

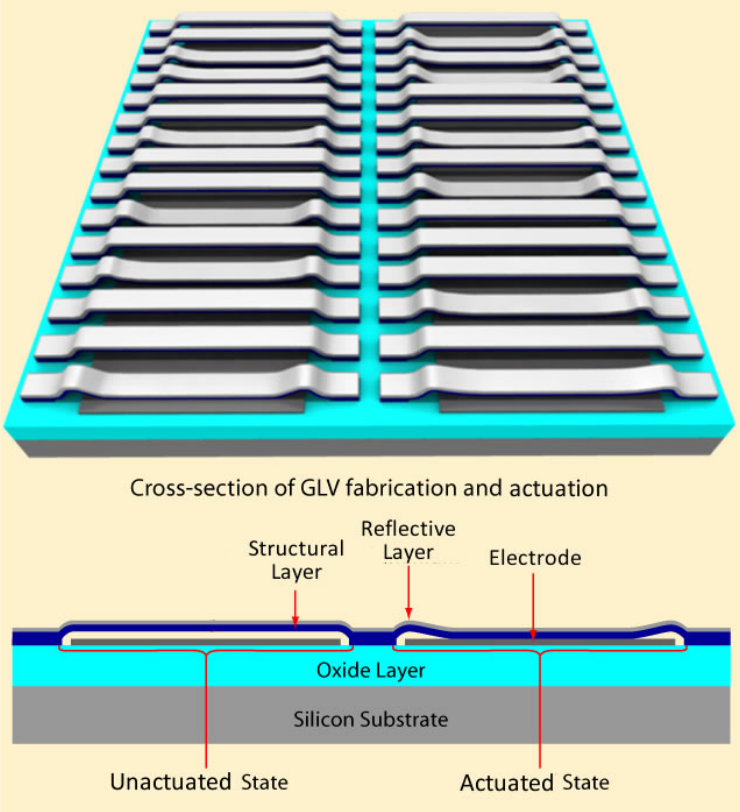
[Images Courtesy of Texas Instruments]





Optical MEMS - Grating Light Valve (GLV)

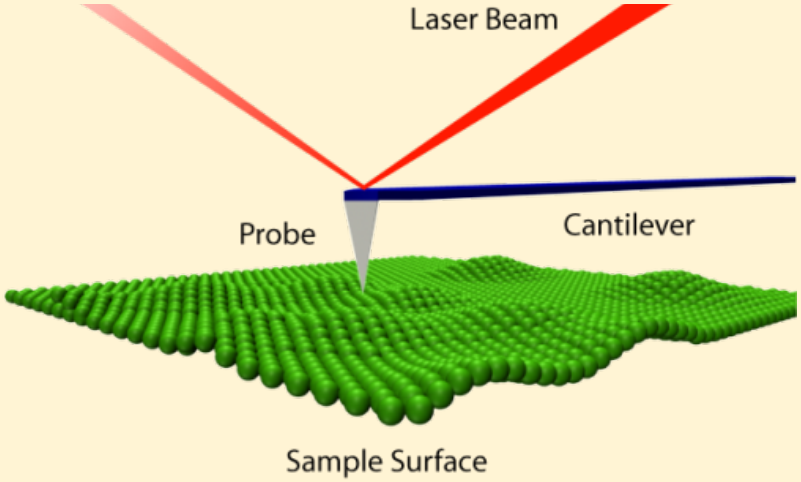
- Silicon nitride ribbons coated with aluminum. A set of four ribbons (two fixed and two moveable) produce a 20 μm square pixel.
- Moveable ribbons are "moved" up and down electrostatically.
- GLVs are used in high definition TVs and are being investigated for use in maskless photolithography.

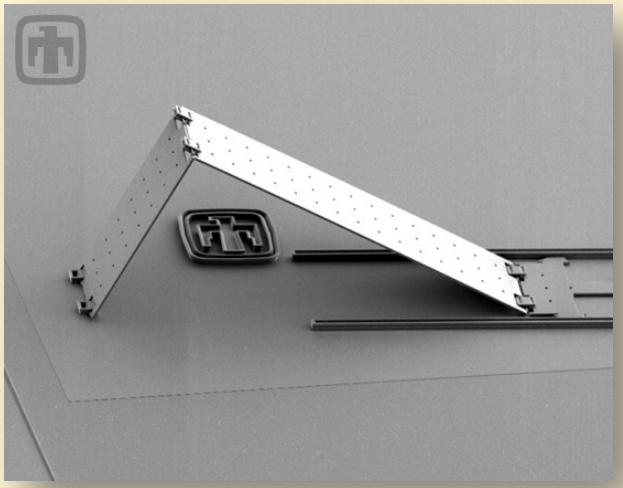


Grating Light Valve (GLV) – top view and side view showing actuated state and unactuated state

Other Optical Applications of MEMS

- Optical Communication Networks
- Display screens on cell phones and PDAs
- Optical Spectrometers
- Bar code readers
- Micromirrors
- Atomic Force Microscopes



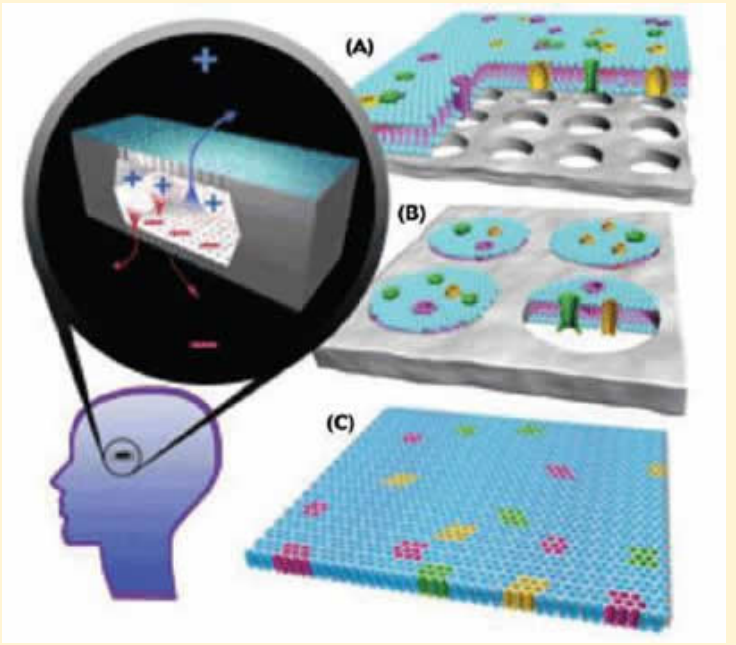


MEMS Pop-up mirror for optical applications. Notice the hinge allowing for the different angles needed to direct light in different directions. Also notice the track that assists in positioning the mirror at the correct angle.

[Image Courtesy of Sandia National Laboratories SUMMIT™ Technologies, www.mems.sandia.gov]

More MEMS

Zyvex Microgrippers
[Printed with permission © 2002 Zyvex]



In vivo battery to power artificial retina arrays
[Courtesy of Sandia National Laboratories]

Cyborgs and Drones

Summary

The automotive industry was one of the first industries to embrace the use of MEMS. Since then, MEMS have found applications in wireless communications, biomedical, aerospace, and consumer products (to name a few).

The potential uses for MEMS are endless.

Acknowledgements

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