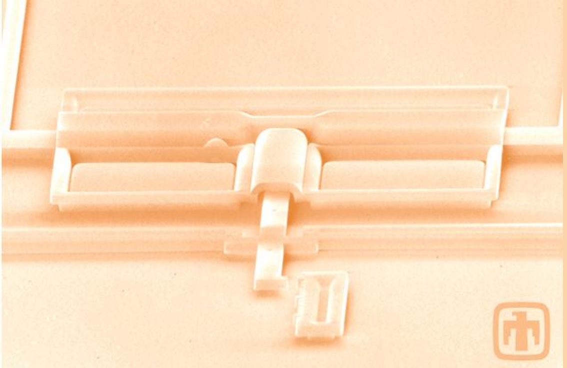
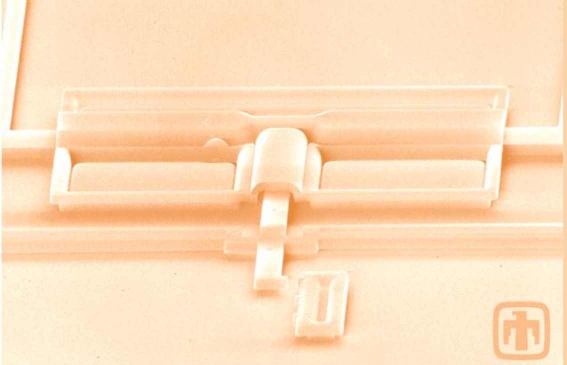


MEMS 101
Introduction to Microsystems

Presented by

Southwest Center for
Microsystems Education
-SCME-

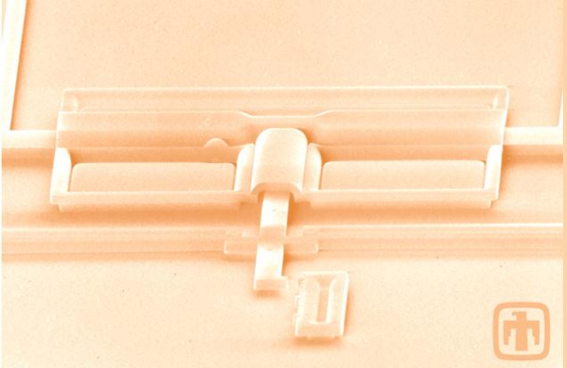


SCME
Southwest Center for Microsystems Education

SCME is a National Science Foundation Advanced Technological Education (ATE) Program at the University of New Mexico.

We offer professional development and educational materials to excite and engage high school, community college and university students in the field of Microsystems (MEMS) technology.

Support for this work was provided by the National Science Foundation's Advanced Technological Education (ATE) Program through Grants #DUE 0992411.



Our Presenters

Barb Lopez

Research Engineer, University of New Mexico and Instructional Designer, SCME

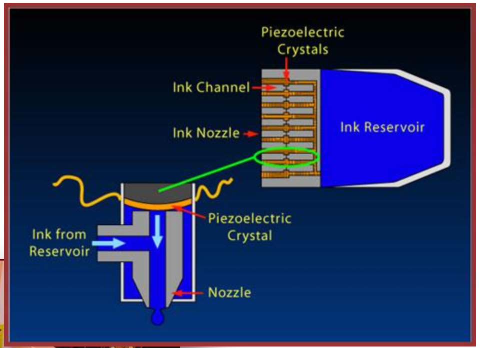
Mary Jane (MJ) Willis

Instructional Designer, SCME and retired Chair for the Manufacturing Technology Program – Central New Mexico Community College

Objectives for Today

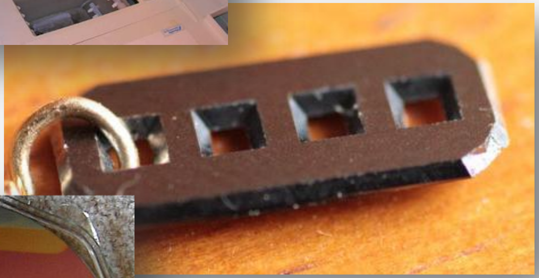
- What is the Southwest Center for Microsystems Education (SCME)?
- What is the difference between microsystems and MEMS?
- What are microsystems?
- How do microsystems affect you?
- What are some examples of MEMS?
- How did microsystems technology evolve?
- Where is microsystem technology headed?

Educational Materials



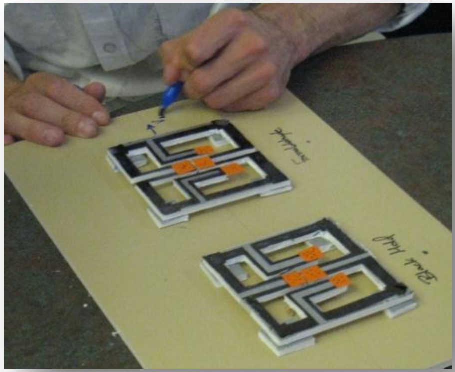
To date SCME offers

- 150 Shareable Content Objects (SCOs)
  - Informational Units / lessons
  - Supporting activities
  - Supporting assessments
- 37 Learning Modules in the areas of
  - Safety
  - Microsystems Introduction
  - Microsystems Applications
  - Bio MEMS
  - Microsystems Fabrication
- 11 Instructional Kits
- All are available @ scme-nm.org



SCME
Southwest Center for
Microsystems Education

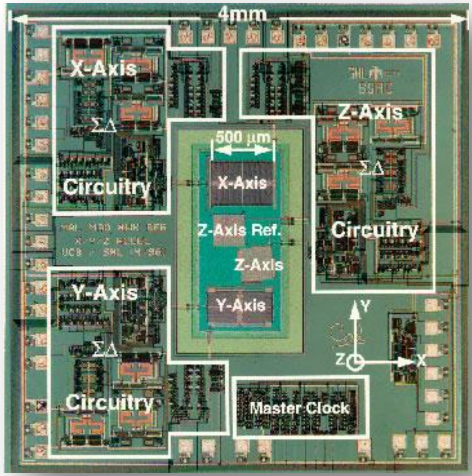
Professional Development



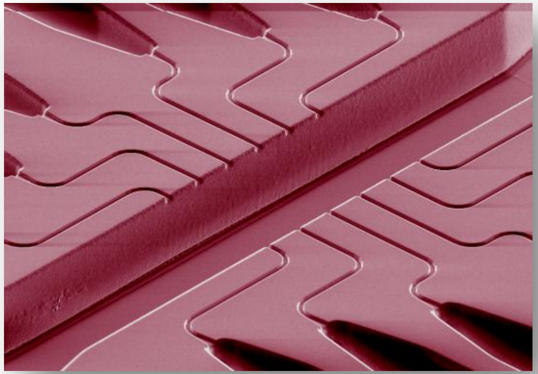
- 5-day workshops
- 2-day workshops
- 1-day workshop
- Conferences and conference workshops
- Create hubs at other colleges to teach our workshops
- Webinars

Microsystems vs. MEMS

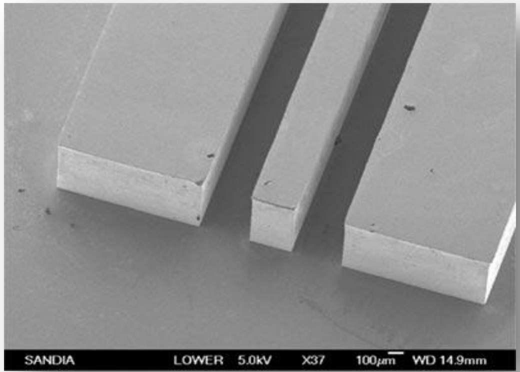
- MEMS = Micro-electro-mechanical-systems
- Microsystems is all encompassing
  - MEMS
  - Micro-optics
  - Microfluidics
  - Biomolecular
  - Semiconductors



MEMS
3-axes accelerometer with electronic interface, used for airbag deployment
[Courtesy of Sandia National Laboratories]



Microfluidics
Channels and chambers
[Courtesy of Luke Lee @ UC-Berkeley]



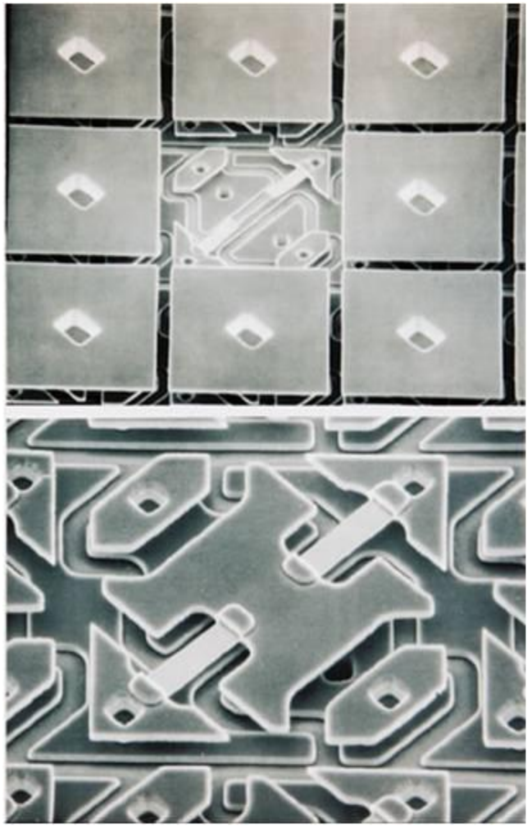
Waveguides *for RF and microwaves, optics and fluids*
[Courtesy of Sandia National Laboratories]

Microsystems Technologies

Micro-Optics:

Digital Mirror Device (DMD)

Digital projection, optical metrology, and optical networking

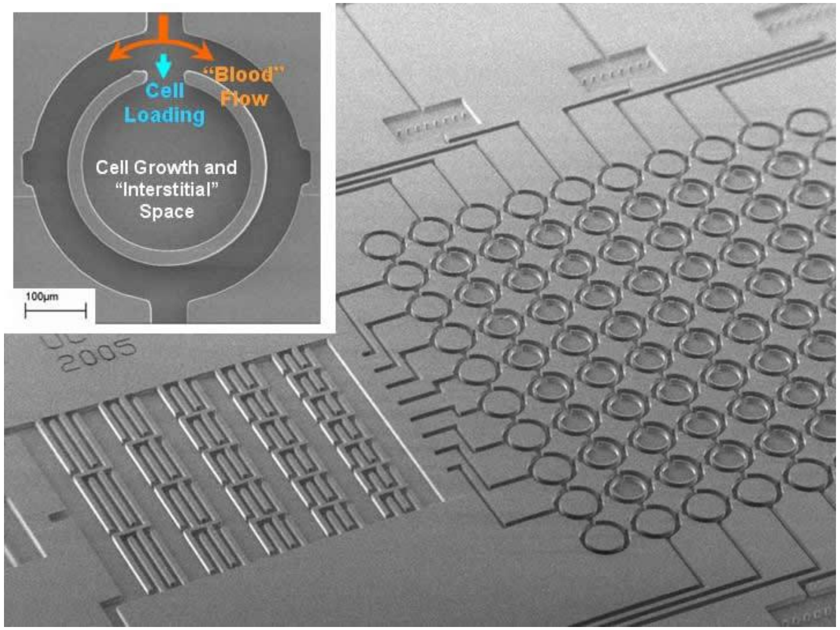


Microfluidics:

Cell Culture Environments

A microenvironment for growing cells in vitro and in parallel, allowing for the analysis of multiple cell growth conditions.

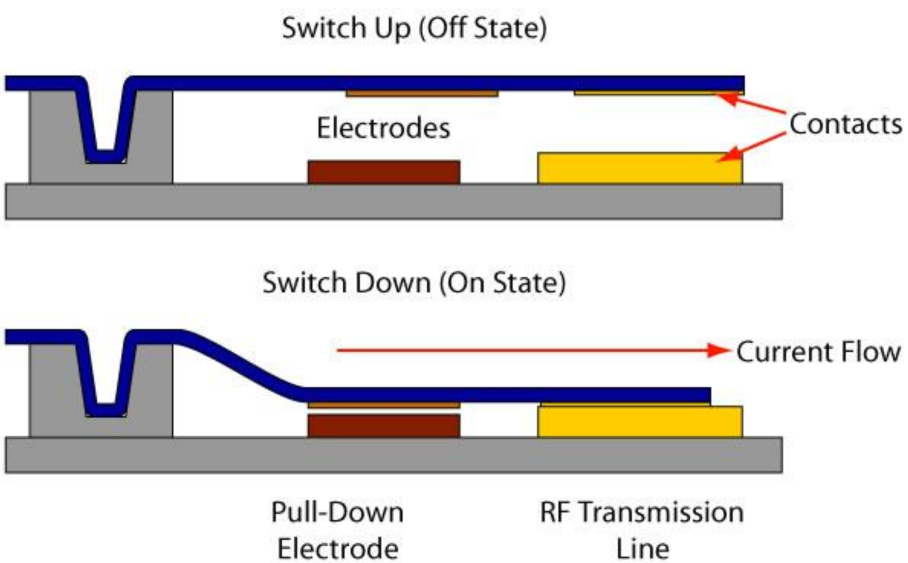
[Developed by and courtesy of BioPOETS Lab, UC-Berkeley]



Microsystems Technologies

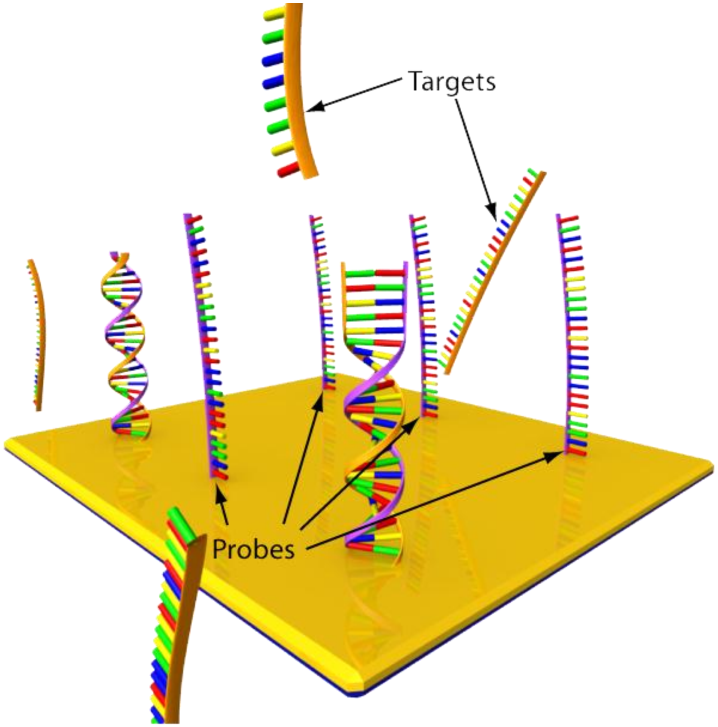
RF and Microwave Micro-Components

Switches, resonators, variable inductors and capacitors, oscillators



Biomolecular Applications

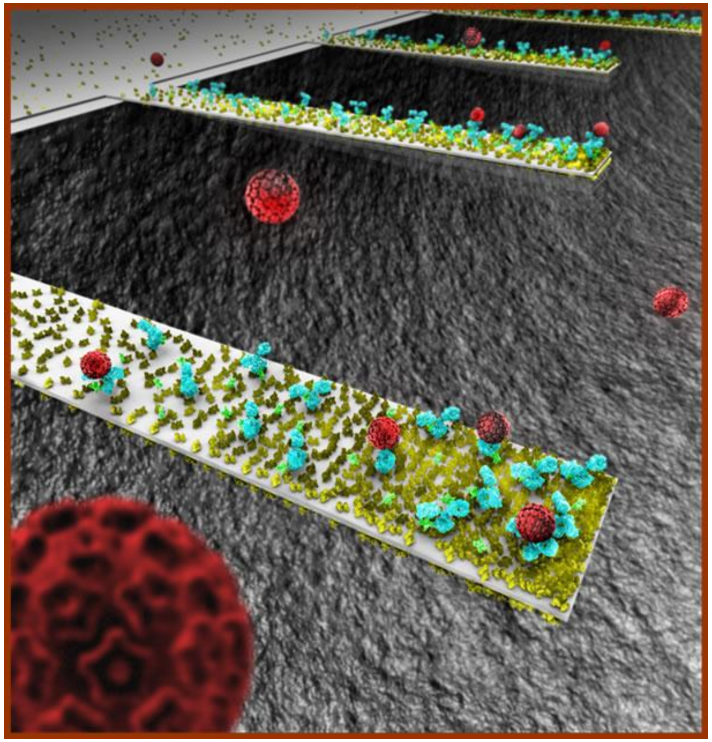
DNA microarrays use synthetic ssDNA to identify complementary ssDNA from patient samples



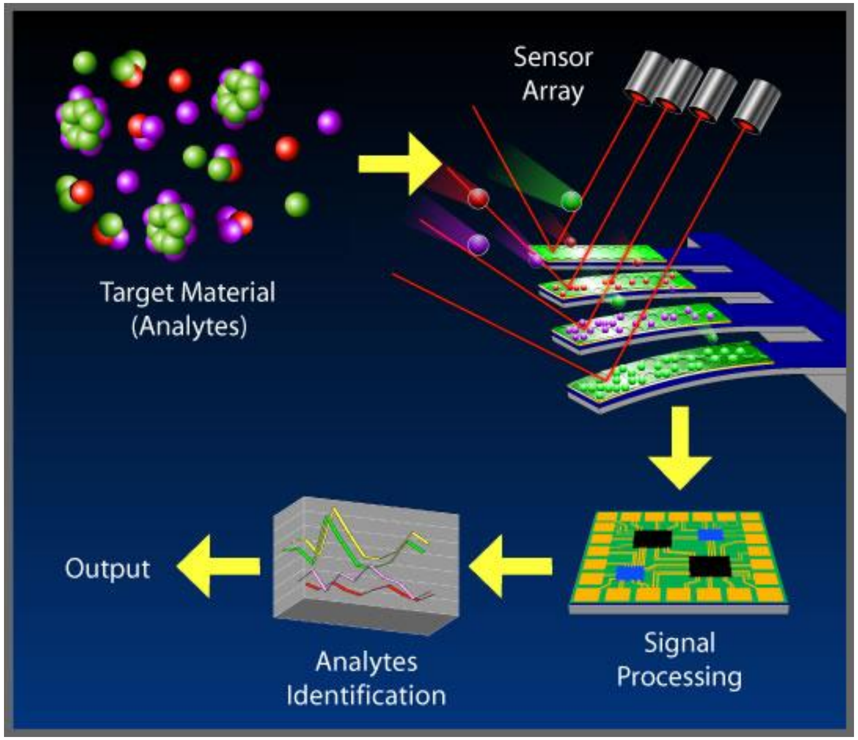
Microsystems Technologies

MEMS and Biomolecular Applications

MEMS cantilevers are fabricated with surface coatings allowing for the identification and rejection of specific biomolecules.



[Image generated and printed with permission by Seyet, LLC]



Microsystems vs. MEMS

In short,

MEMS are Microsystems

Today, the terms MEMS and Microsystems have become interchangeable; therefore, you will see us use both terms throughout this presentation.

At some point you may also see “MST” or Microsystems Technologies. This is the term commonly used in European countries. “

What is a microsystem?

- Any system fabricated with the smallest components in the micro-scale
- Comparison of Scales – Macro, Micro and Nano

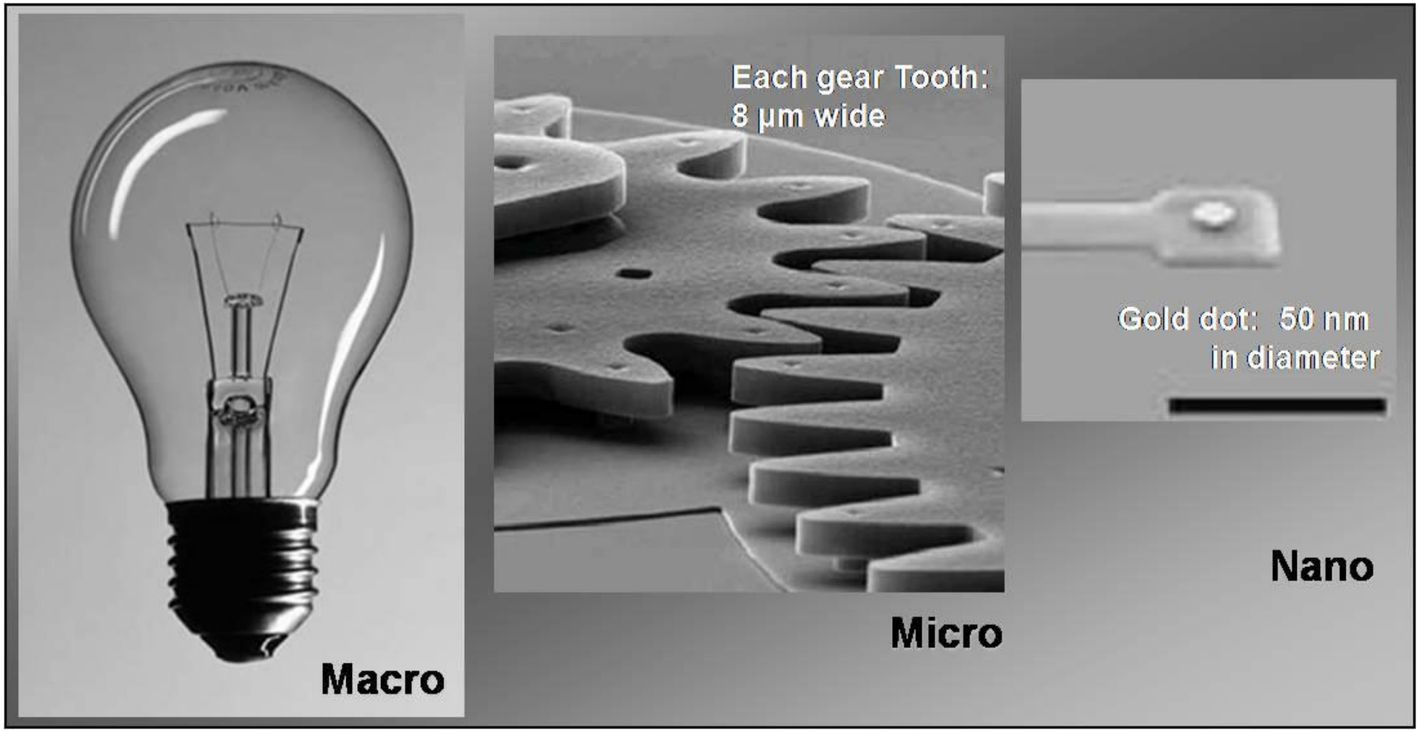
Which of the following represent the Macro, Micro and Nano scales, respectively?

a. > 999 micro, 999 micro to 999 nano, 999 nano to 1 nano
b. > 100 micro, 100 micro to 100 nano, 100 nano to 1 nano
c. > 10 micro, 10 micro to 10 nano, 10 nano to 999 pico
d. > 10 micro, 10 micro to 1 nano, 1 nano to 100 pico

Comparison of Scale

Answer: **b**

> 100 micro   100 micro – 100 nano   100 nano – 1 nano



[Micro image of microgears courtesy of Sandia National Laboratories]
[Nano image Printed with permission Craighead Group/Cornell University and © Cornell University]

Scale of Measurement

- Millimeter (mm): 1x 10^{-3}
- Micrometer (μm): 1x 10^{-6}
- Nanometer (nm): 1x 10^{-9}
- Angstrom (Å): 1x 10^{-10}
- Picometer(pm): 1x 10^{-12}

Macro, Micro, or Nano?

Place each of these 4 items in the Macro, Micro, or Nano scale

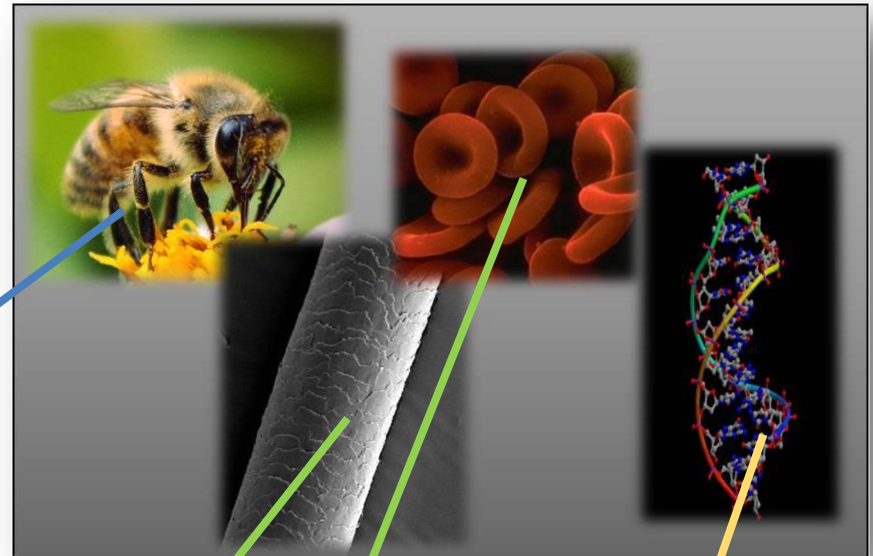
Macro

Micro

Nano

Macro, Micro, or Nano?

Place each of these 4 items in the Macro, Micro, or Nano scale



12 mm

60-100 μm

7 μm

2 nm

Macro

Micro

Nano

Macro vs. Micro-size Devices

Compared to macroscopic devices micro-size devices are

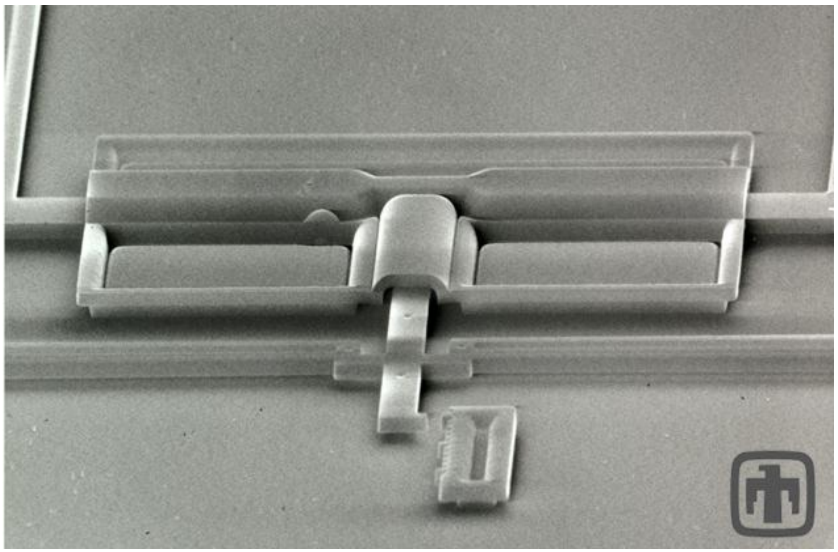
- much smaller,
- much lighter,
- more energy efficient, and
- constructed with fewer materials.

In equivalent applications, micro exceeds macro devices in

- reliability,
- efficiency,
- selectivity,
- response time, and
- energy consumption.

Macro vs. Micro-size Devices

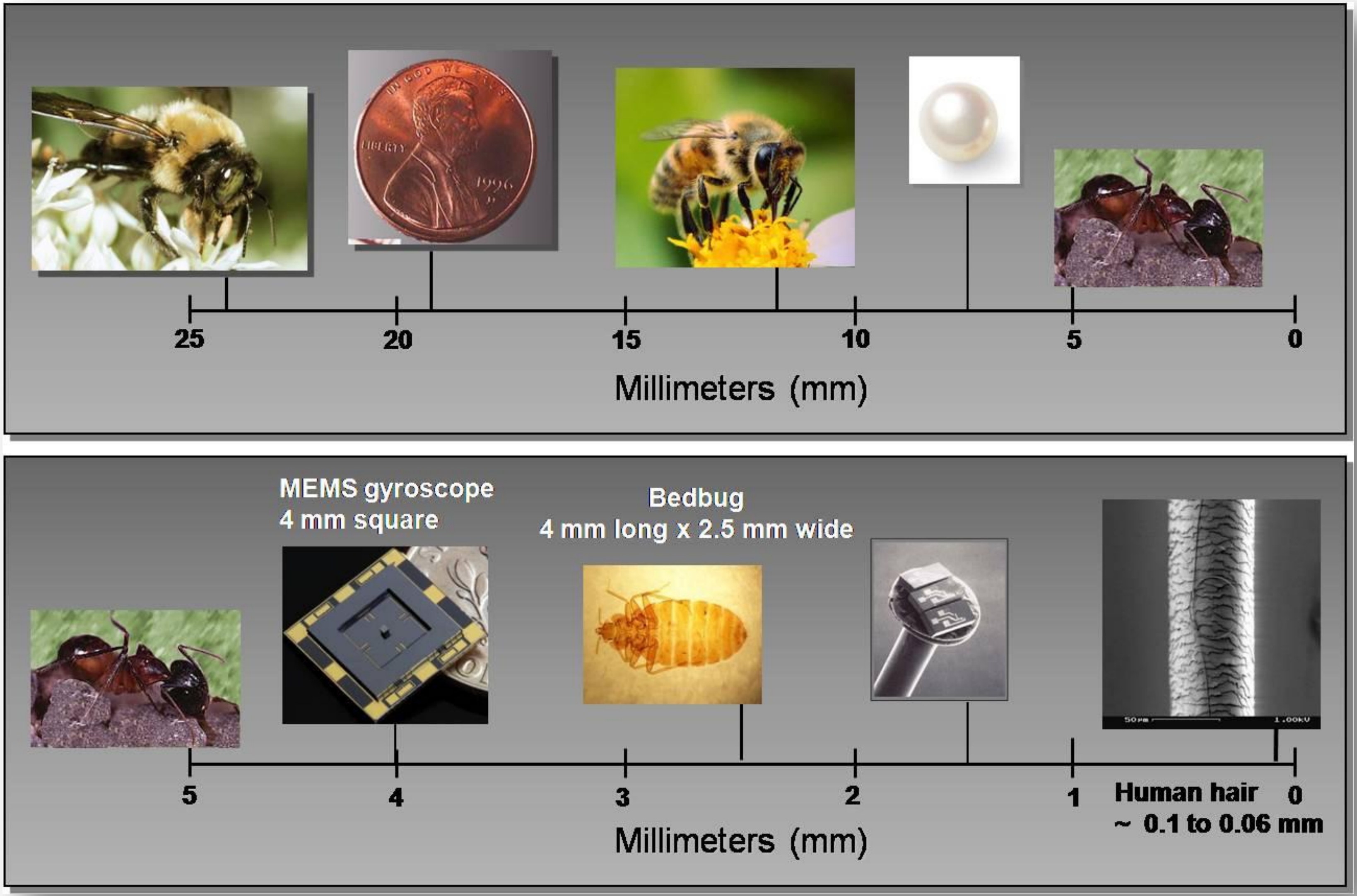
Steam locomotive
[Courtesy of and photo credit by Ashley Dace. Wikipedia – Steam Engines]



A single-piston micro-steam engine less than 100 µm wide.
[Courtesy of Sandia National Laboratories, SUMMiT(TM) Technologies, www.mems.sandia.gov]

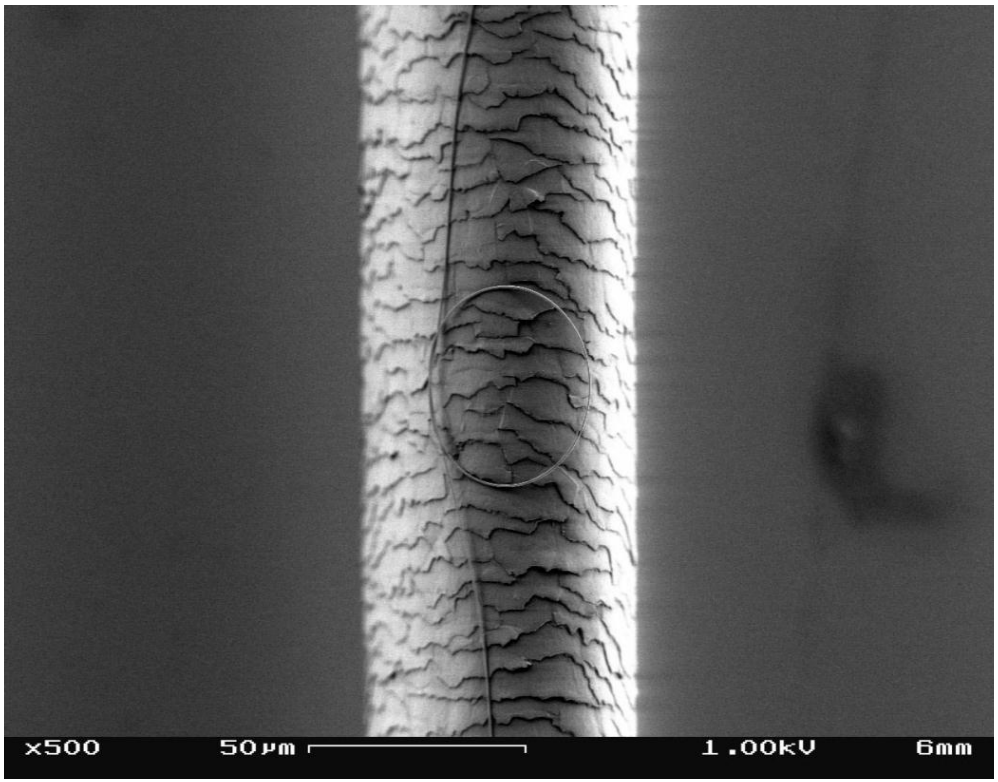
This technology has lead to the development of micro-sized generators, heat exchangers, and pumps. In its development, Sandia solved many of the problems associated with transport processes and material interactions at the microscale.
[MEMS Sheds Light on Material Interactions. ASME. Aug 2011]

Macro vs. Micro vs. Nano



Micro vs. Nano

- Looking closer at the 60 to 70 μm diameter hair, you can see a nanowire which is approximately 50 nanometers in diameter.

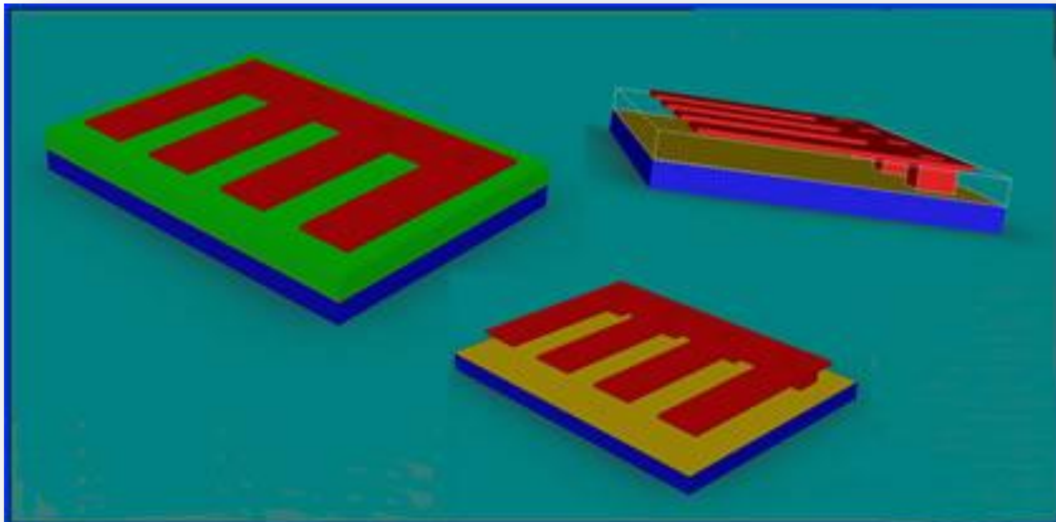


Micrograph of a nanowire curled into a loop in front of a strand of human hair. The nanowires can be as slender as 50 nanometers in width, about one-thousandth the width of a hair.

Credit: Limin Tong/Harvard University [Courtesy of the National Science Foundation]

Micro vs. Nano

- In addition to the actual size of the objects, fabrication is another primary difference between micro and nanotechnology.
- Microtechnology uses the "top down" approach

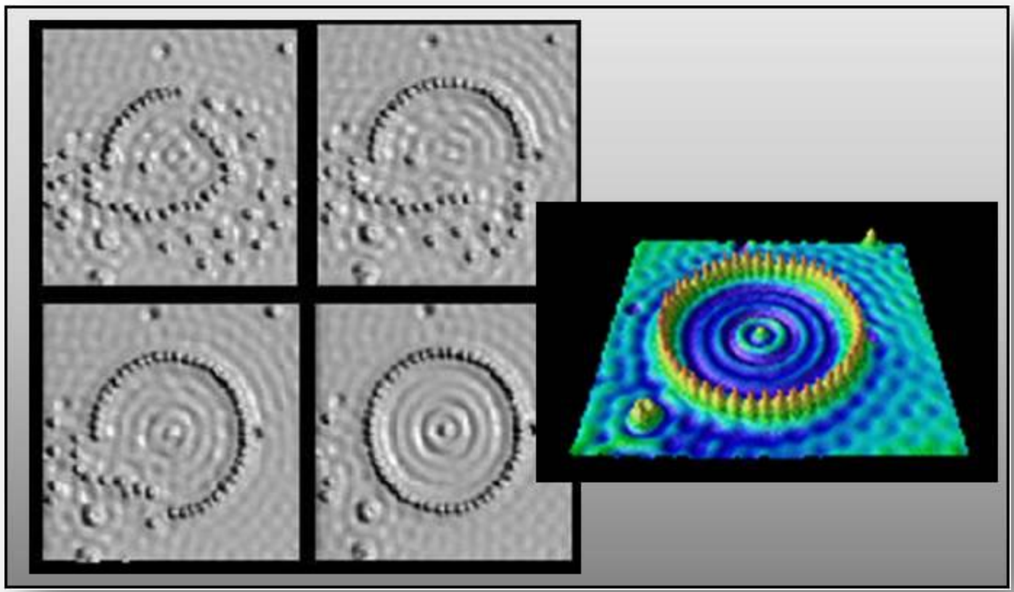


Creating suspended cantilevers (red) by selective removal of a layer (green)

[Animation of Cantilever "release"]

Micro vs. Nano

- Nanotechnology can use what is referred to as the "bottom up" approach to fabrication.

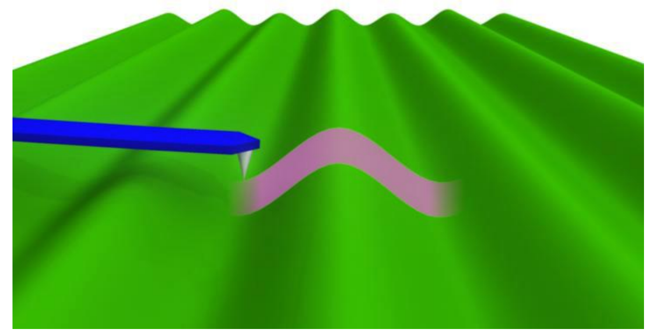


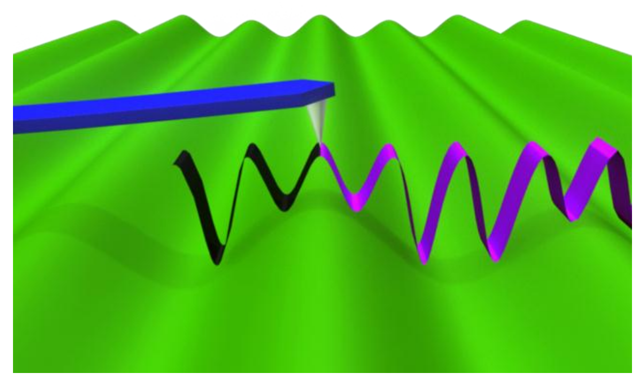
Assembly a quantum corral (left) made by placing 48 iron atoms in a circle, one at a time, onto the surface of gold.
[IBM STM Photo Gallery]

Individual atoms can be manipulated into place using instrumentation such as Atomic Force Microscopes (AFM) or structures can be formed using the biological characteristic of “self-assembly”.

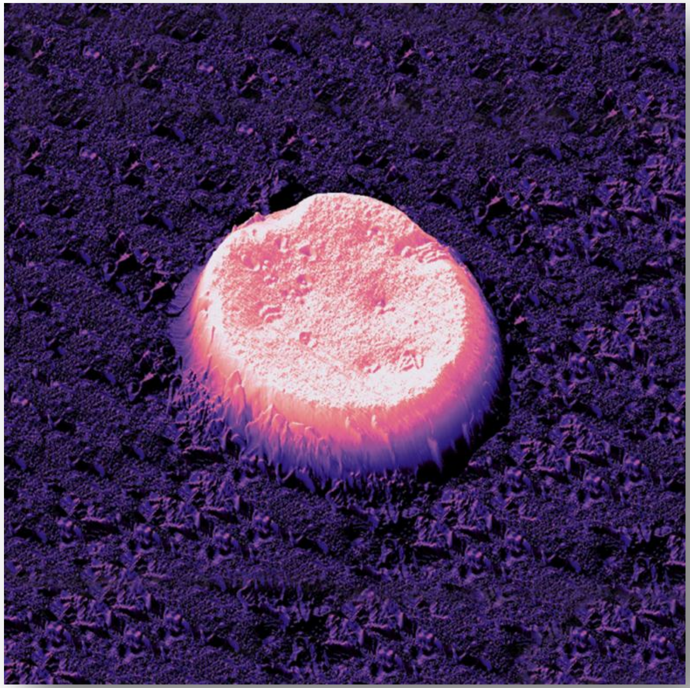
Nano meets Micro

- The smaller microsystems become, the smaller their components become.
- Systems currently exist that have both micro and nano-size components. Such systems fall under the category of nanotechnology because of the nano-size components.
- Example: Atomic Force Microscope (AFM) – Cantilever can be 2 - 20 µm wide. The probe tip can be as big as 2 µm, but as small as 10 nanometers.

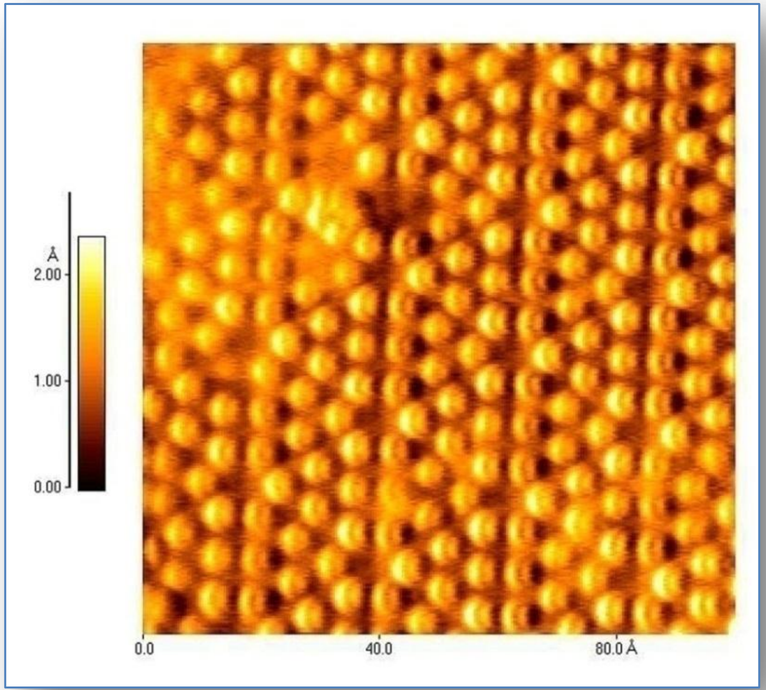




Images created by an AFM



Atomic Force Microscope image of an erythrocyte (red blood cell). Photo: nanoAnalytics GmbH
[Printed with permission by Nano2Life.]



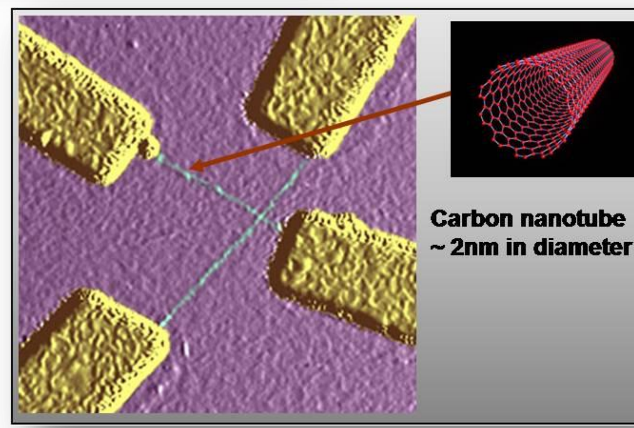
AFM image of dozens of silicon atoms showing electron paths as small as 1 Angstrom in diameter *[Printed with permission. See F. J. Giessibl et al., Science 289, 422 (2000)]*

How Big is Small?

- One light-year is 9,460,730,472,580.8 km.
- One kilometer (km) is 1000 meters.
- One micrometer is 10^{-6} (a millionth) of a meter.
- One nanometer is 10^{-9} (a billionth) of a meter.
- One Angstrom (Å) is 10^{-10} of a meter

The Milky Way Galaxy is 100,000 light years (9.5×10^{17} km) in diameter

The Milky Way [Image credit: NASA/JPL-Caltech[2]]



0.3 to 0.2 micrometer wide electrodes (gold) joined by 2.0 nanometer (20 Å) connectors or nanotubes (green)

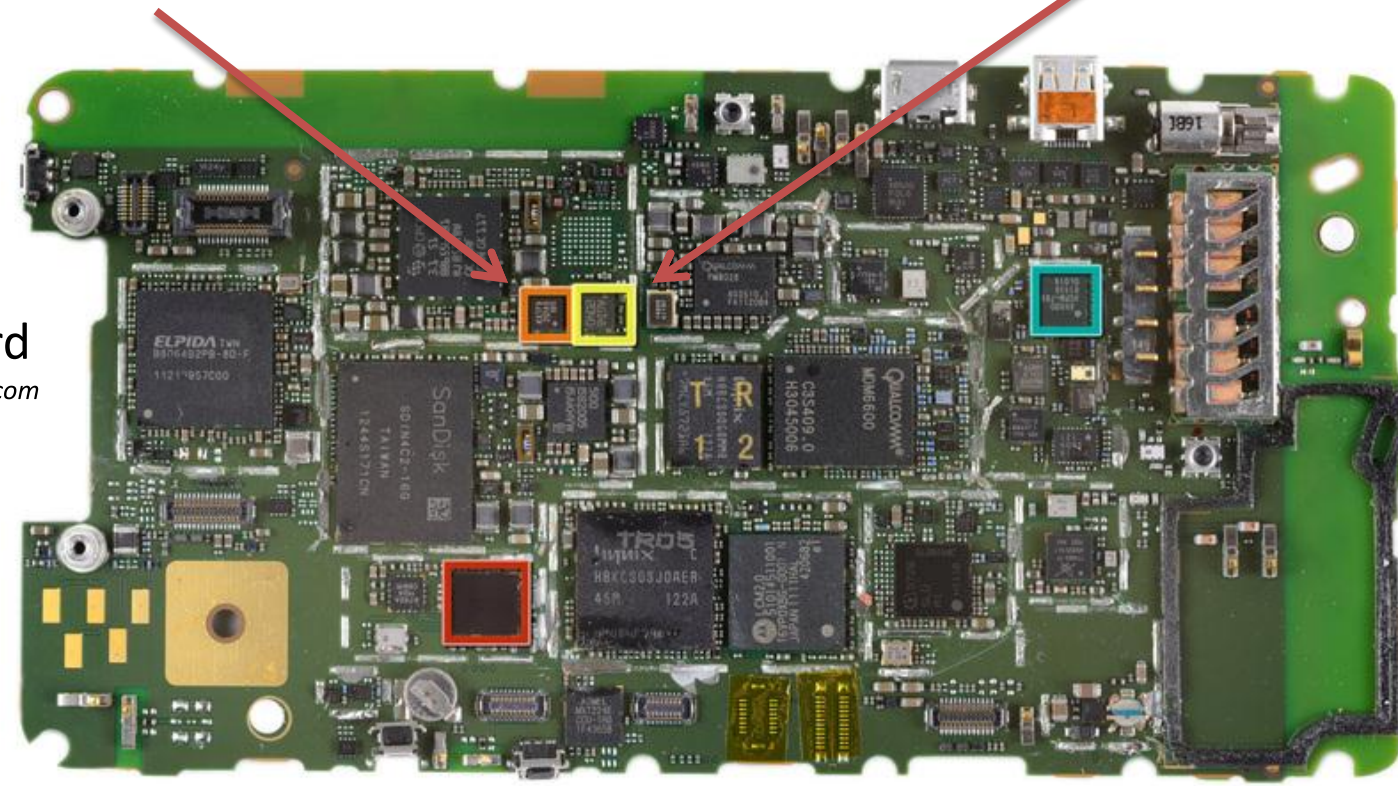
[Printed with permission. See F. J. Giessibl et al., Science 289, 422 (2000)]

How do microsystems affect you?

What are some microsystems or micro-size devices that affect your daily lives?

Question

- How about smart phones, cameras, laptops, gaming devices? They all have MEMS inertial sensors (gyroscopes and accelerometers).



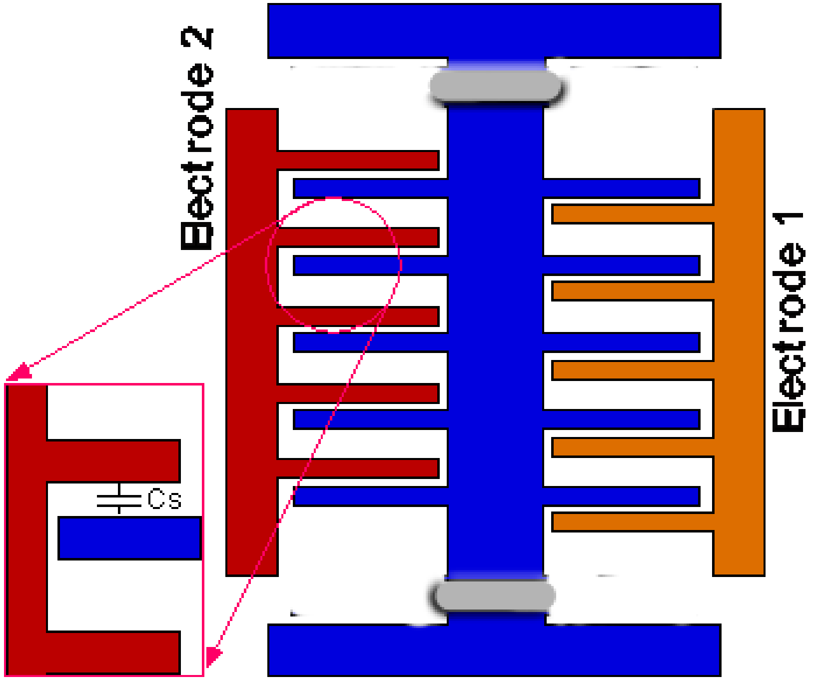
Droid Card
Courtesy of ifixit.com

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

Inertial Sensors

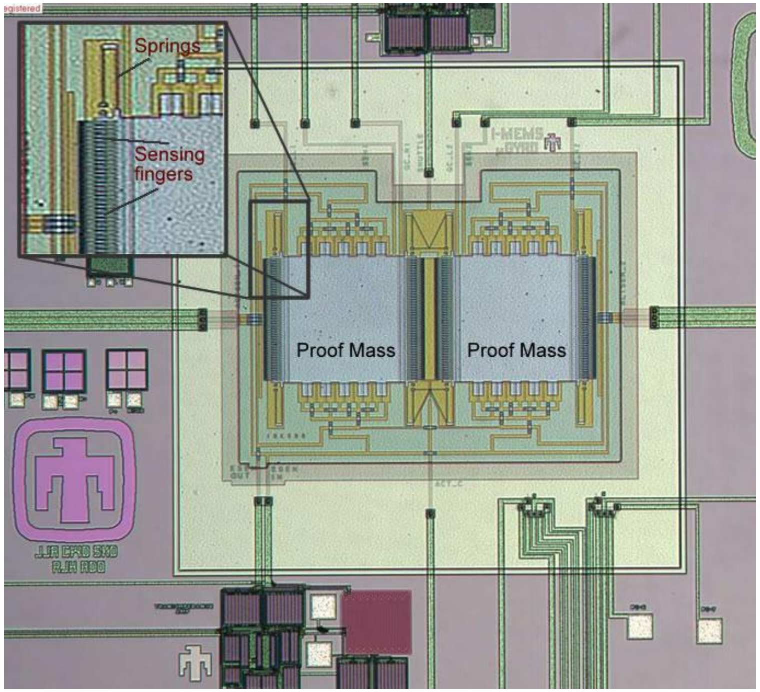
- MEMS inertial sensors can detect acceleration, vibration, shock, tilt and rotation.

MEMS Accelerometer



MEMS Gyroscope

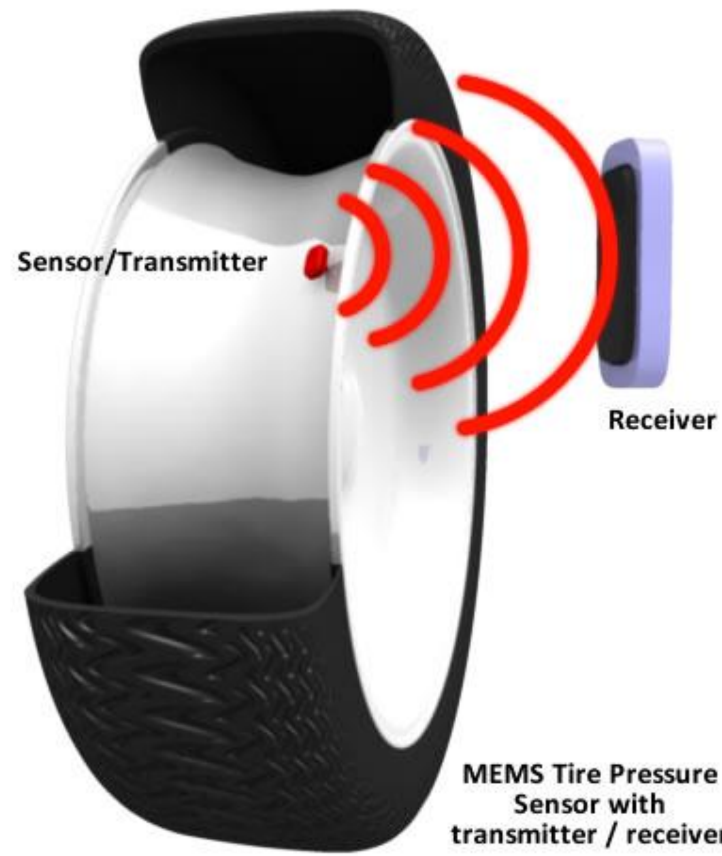
[Courtesy of Sandia National Laboratories]



How do microsystems affect you?

MEMS in the automotive industry

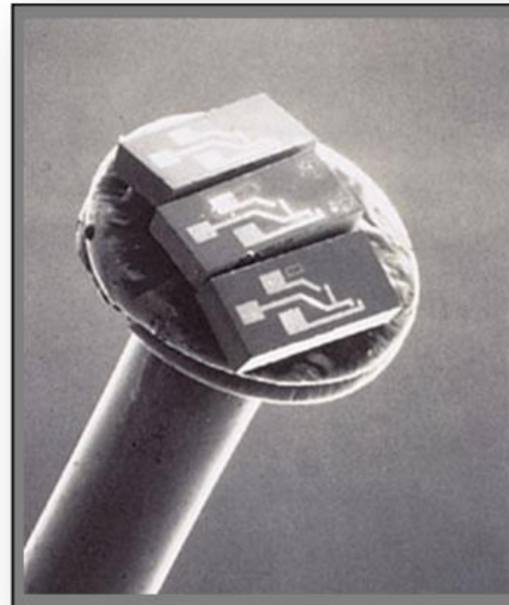
- Tire pressure
- Fuel pressure
- Oil pressure
- Absolute air pressure within the intake manifold of the engine
- Airbag deployment
- Weight and sensing of passengers



How do microsystems affect you?

Biomedical Applications

- Micro-pressure sensors (PS) that measure blood pressure, intracranial pressure
- PS in endoscopes and infusion pumps
- Microgrippers and tweezers for non-invasive surgeries

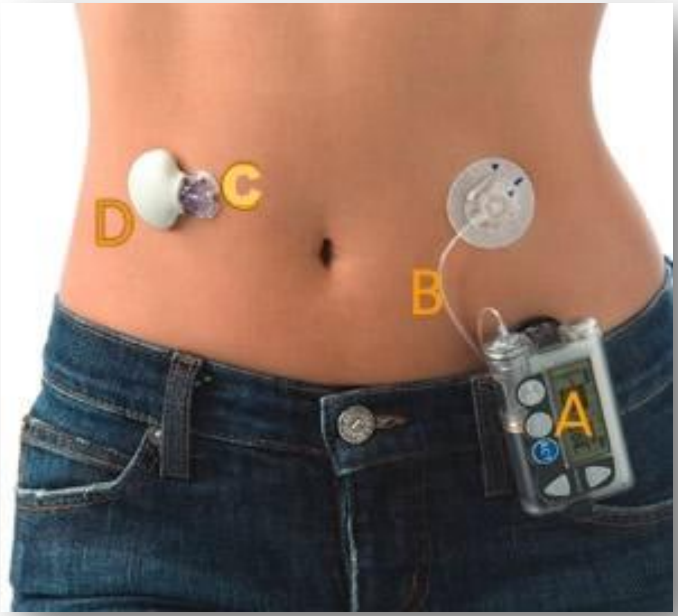


MEMS Blood Pressure Sensors on the head of a pin.
[Photo courtesy of Lucas NovaSensor, Fremont, CA]

These microgrippers are 50 µm thick and opens to 100 µm. Keep in mind that the diameter of a hair is 60 to 100 µm in diameter!
[Developed by and printed with permission © 2002 Zyvex]

How do microsystems affect you?

- Sub-dermal glucose monitoring and delivery of insulin
- Medical diagnostics for blood analysis, cells counts and urinalysis
- DNA microarrays for identification of specific genes and other biological marker

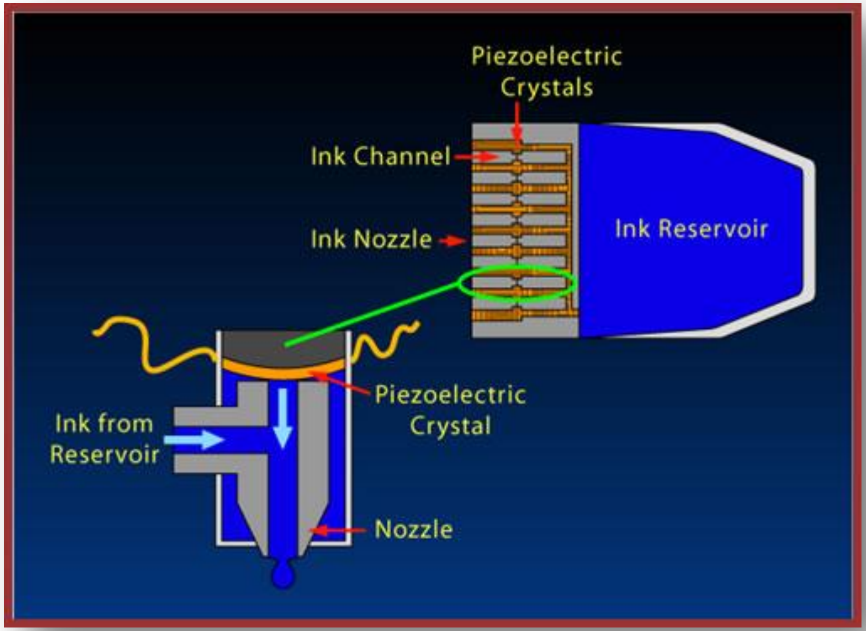


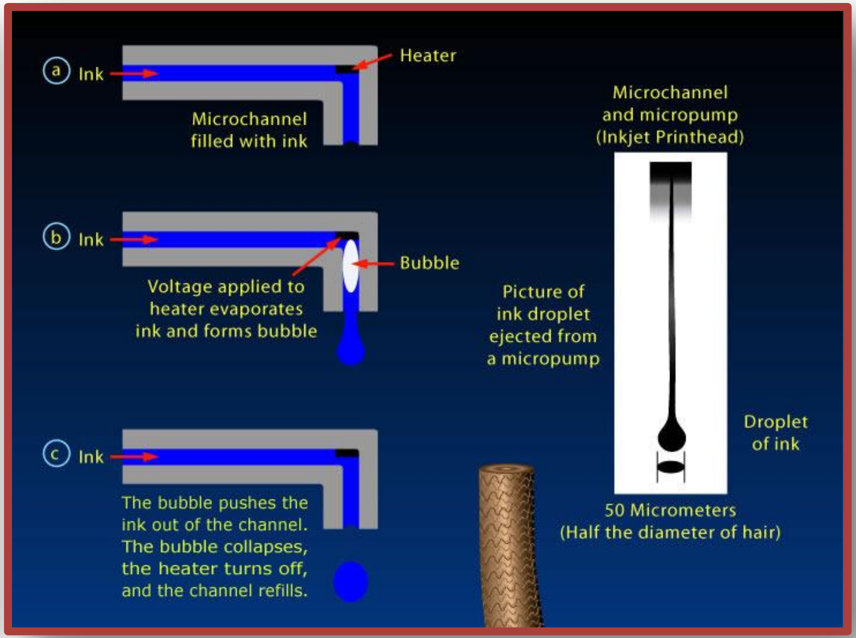
MiniMed Paradigm[R] 522 insulin pump, with MiniLinkTM] transmitter and infusion set.
[Printed with permission from Medtronic Diabetes]

Lab-on-a-chip (LOC)
[Printed with permission. From Blazej,R.G.,Kumaresan,P. and Mathies, R.A. PNAS 103,7240-7245 (2006)]

Inkjet Printers

- Piezoelectric and bubble printers provide high-resolution printing for graphic and photographic images
- Inkjet printheads can layer dots of different colors on top of each other, giving the image a richer appearance.





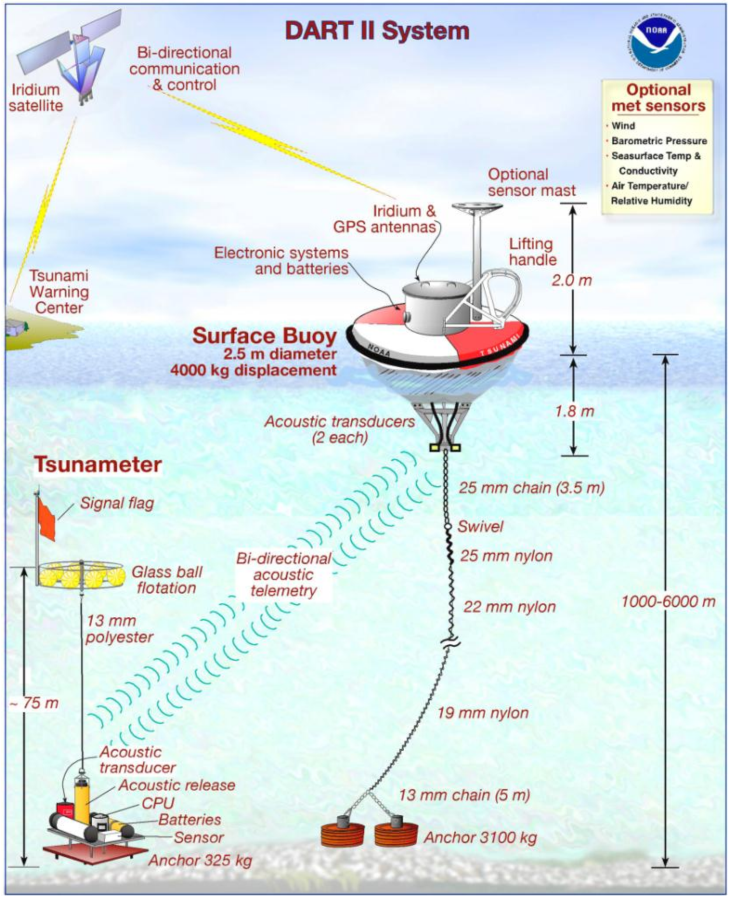
Tsunami Warning Sensors

DART II System MEMS

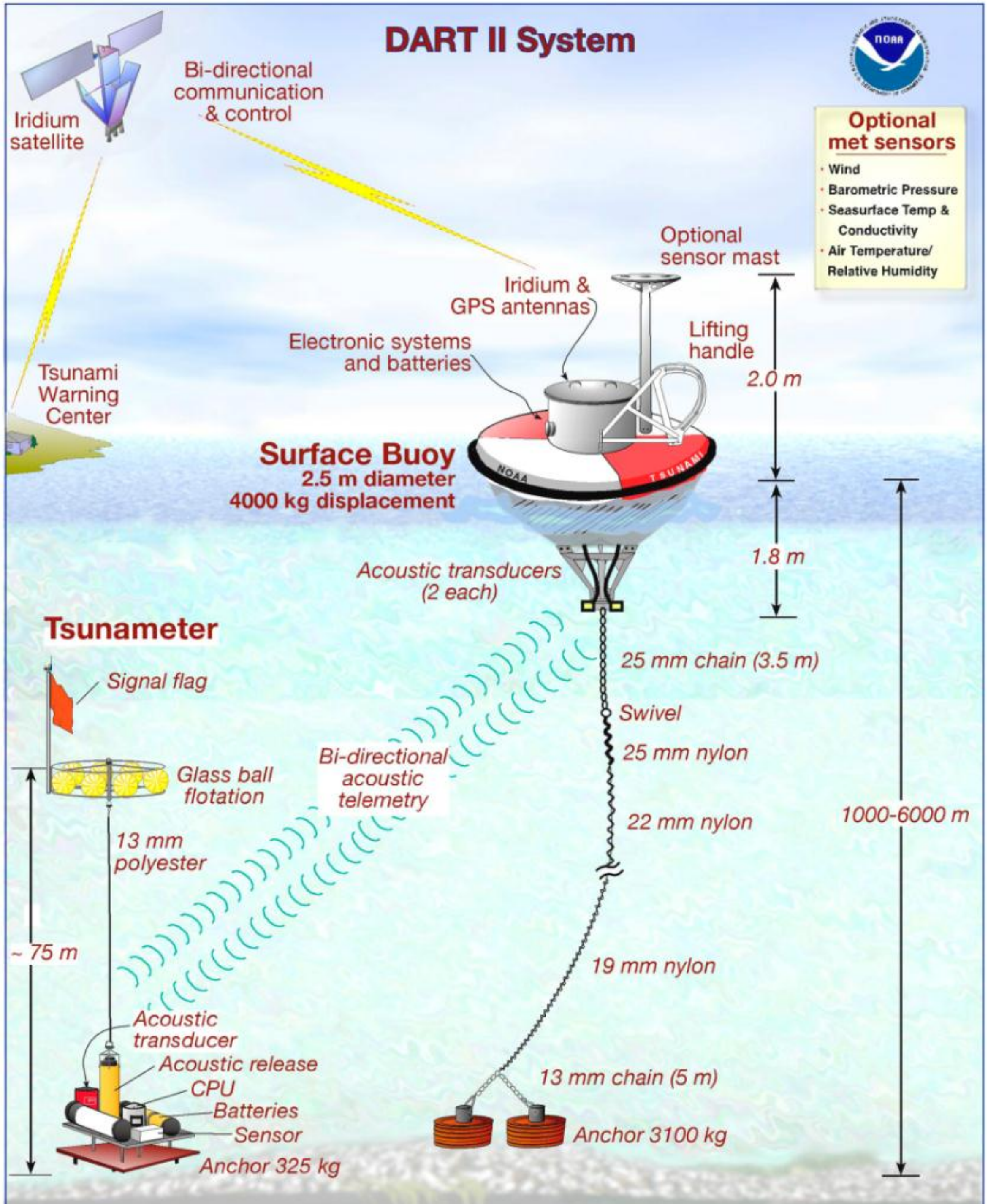
- Pressures on ocean floor
- Ocean surface displacement
- Wind
- Barometric Pressure
- Sea surface temperature and conductivity
- Air temperature
- Relative humidity

DART = deep-ocean assessment and reporting of tsunami

[Diagram courtesy of the NOAA – National Oceanic ad Atmospheric Administration]



Read more about the DART II System at
http://www.noaanews.noaa.gov/stories2008/20080310_buoy.html



[Diagram courtesy of the NOAA – National Oceanic ad Atmospheric Administration]

How Did MEMS evolve?

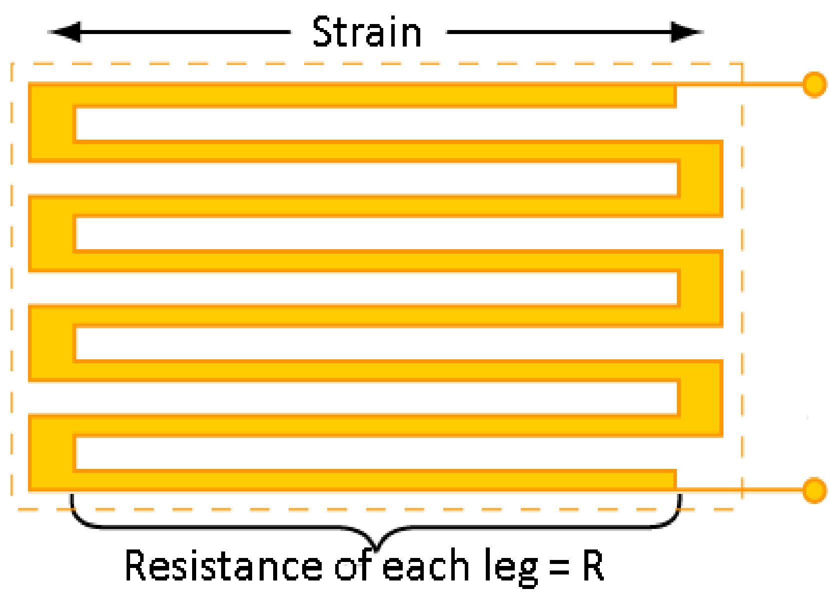
These technologies brought about MEMS as we know them today.

Transistors

First Point Contact Transistor and Testing Apparatus (1947)
[Photo Courtesy of The Porticus Centre]

Piezoresistive Effect

Discovered in 1954. Strained gauges were available commercially by 1958.

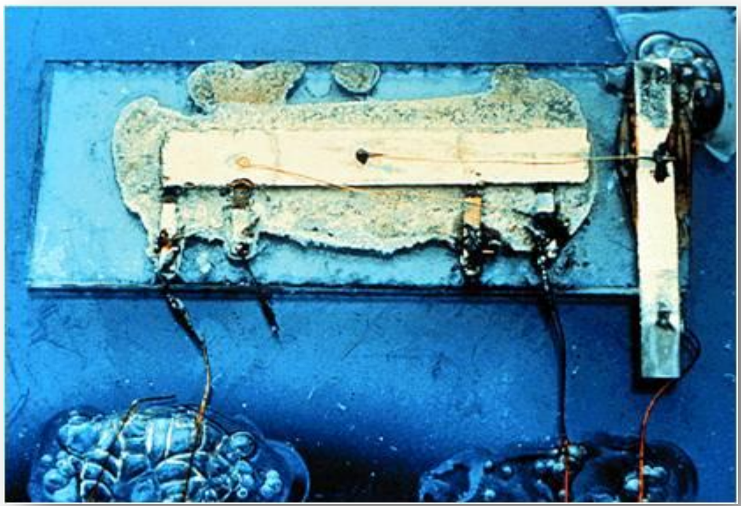


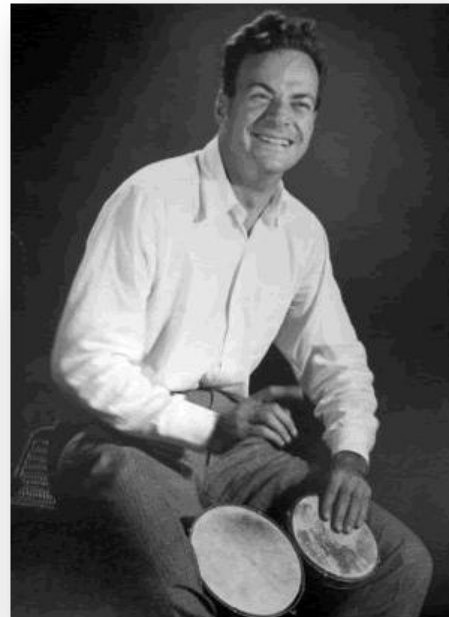
How did microsystems evolve?

Integrated Circuits

Texas Instrument's First Integrated Circuit

[Photos Courtesy of Texas Instruments]





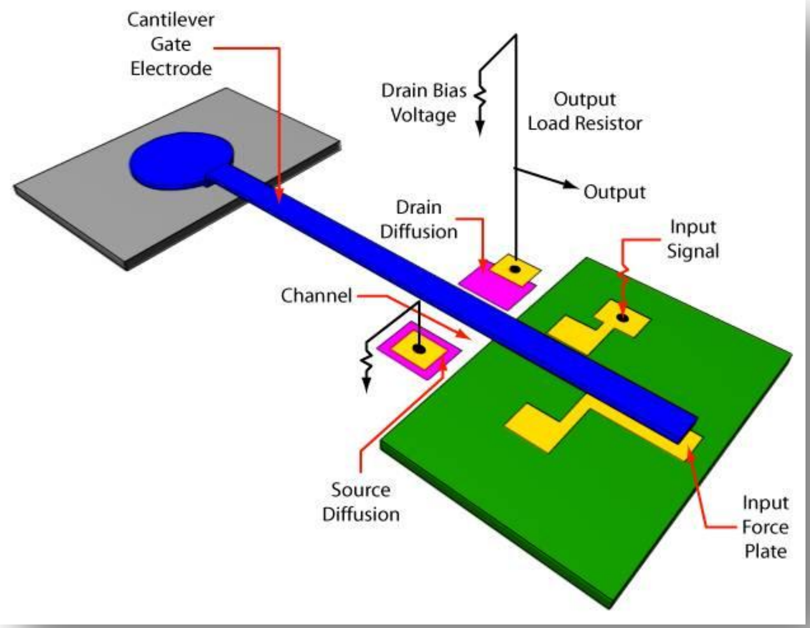
Richard Feynman

[Photo credit: Tom Harvey]

- “There’s Plenty of Room at the Bottom”
- Popularized growth of micro & nano technology
- Introduced the possibility of manipulating matter on an atomic scale

Technologies that brought about MEMS

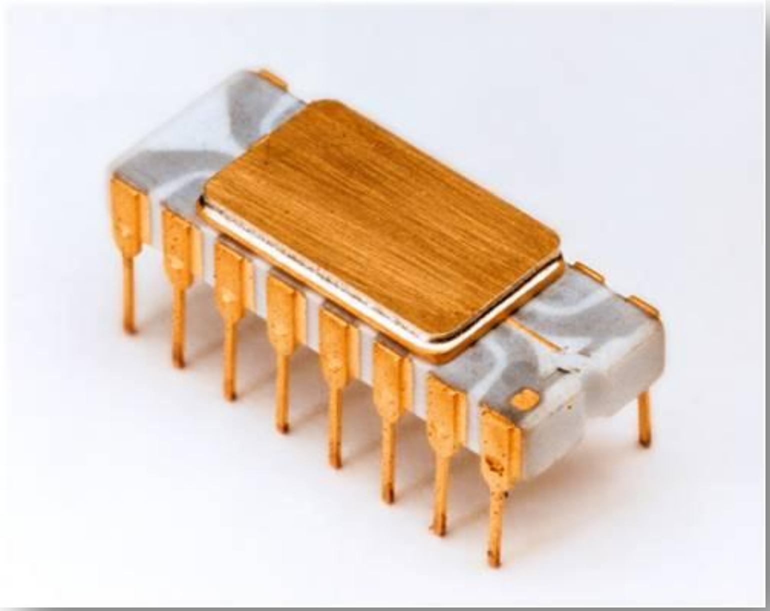
Resonant Gate Transistor



Microprocessor

The Intel 4004 Microprocessor

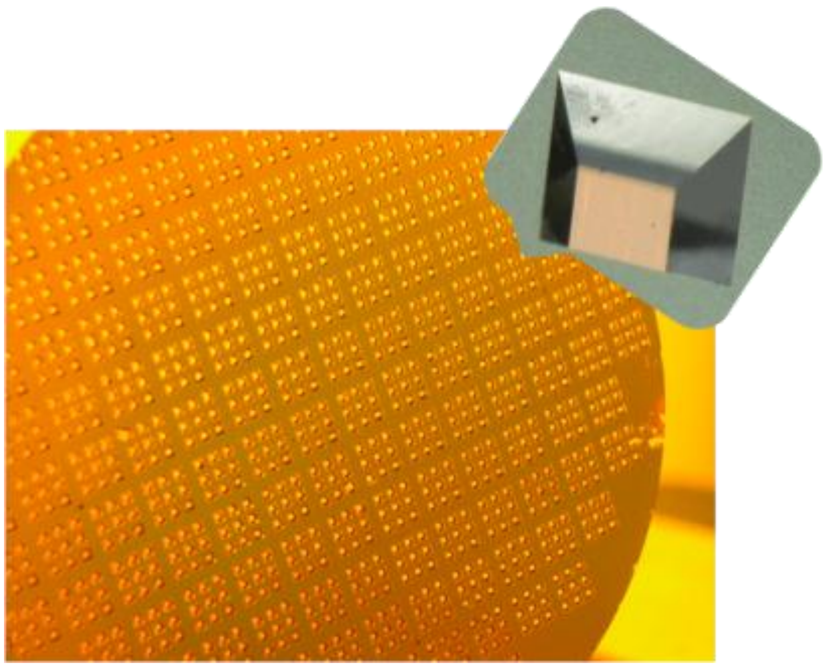
[Photo Courtesy of Intel Corporation]



Technologies that brought about MEMS

Bulk Etching

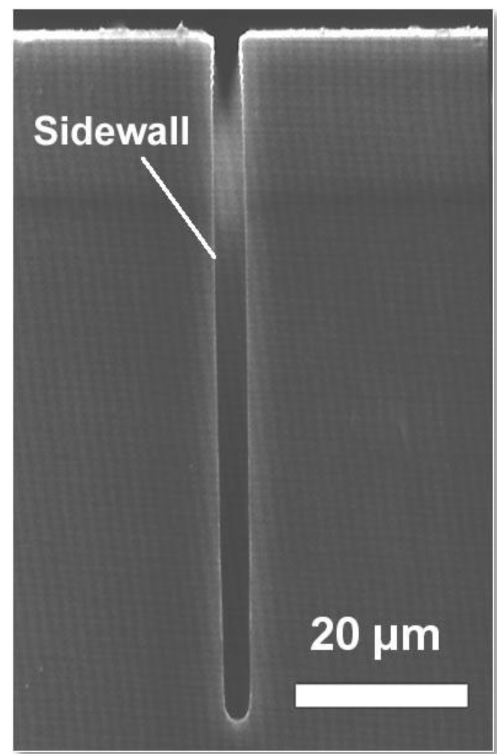
Using wet etch techniques to create deep holes and trenches in silicon as well as removed complete sub-layers



Deep Reactive Ion Etching (RIE)

Using plasma etch techniques to create deep holes and trenches in thin film layers

[SEM images courtesy of Khalil Najafi, University of Michigan]]



Technologies that brought about MEMS

LIGA –

***Li**thographie,*
***G**alvanoformung,*
***A**bformung*

Process that uses lithography, electroplating and electroforming to create micro-size molds and components.

LIGA-micromachined gear for a mini electromagnetic motor

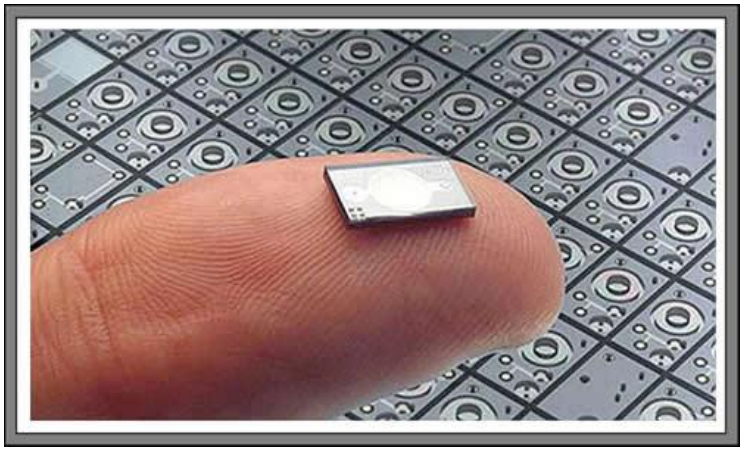
[Courtesy of Sandia National Labs]

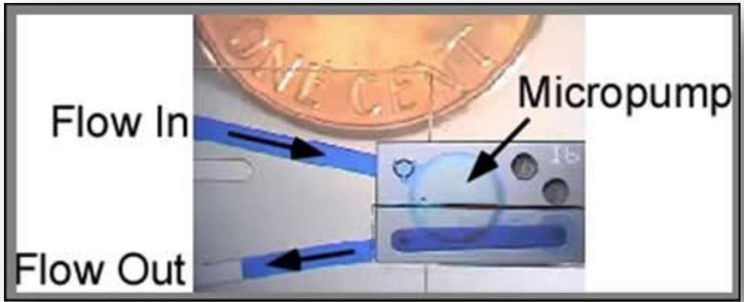
The Outcomes

All of these technologies have lead to the development of a variety of different micro-sized components and devices.

Micropumps

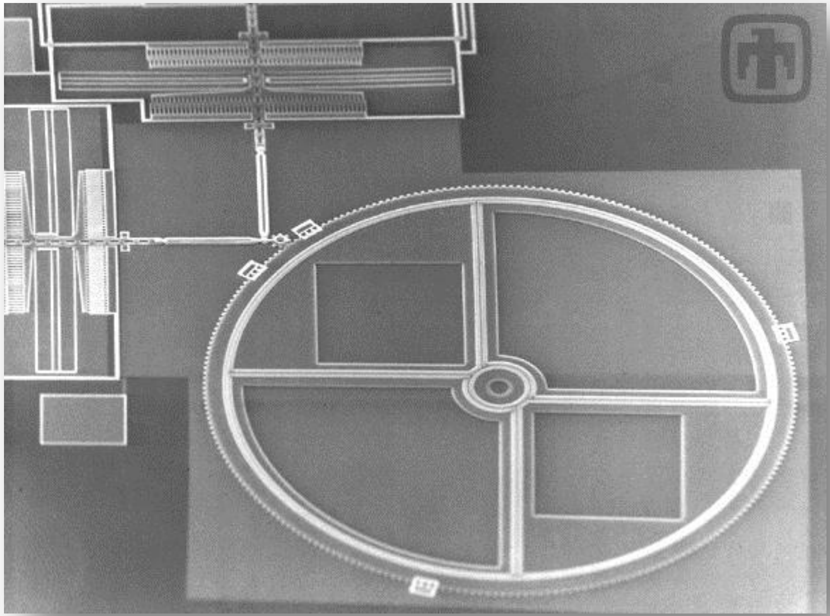
Micropumps for insulin injections
[Courtesy of Debiotech, Switzerland]





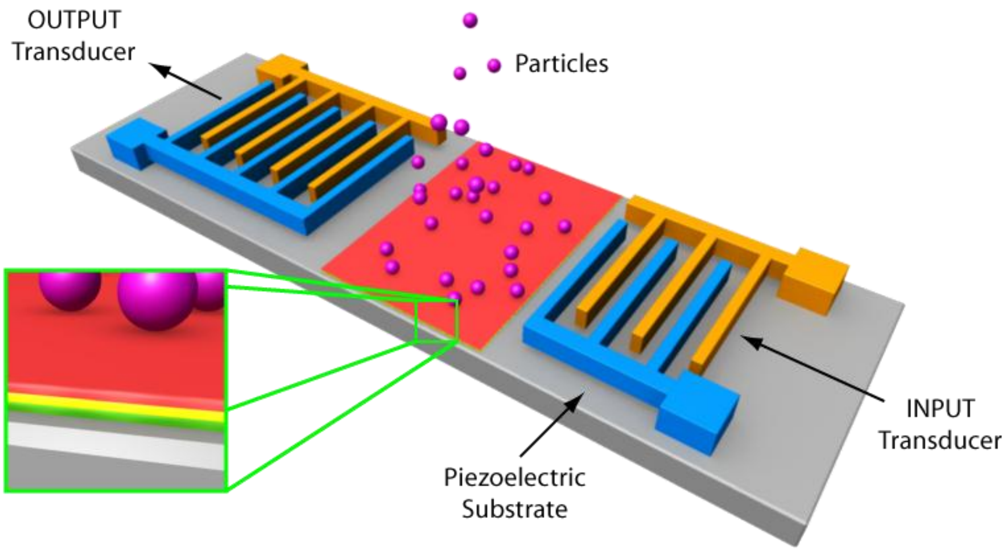
Optical Shutters

In this image are the comb drive motors, linkage mechanisms, and the large optical shutter. Because of the guide rails, the shutter can be rotated at very high speeds.
[Courtesy of Sandia National Laboratories, SUMMiT(TM) Technologies, www.mems.sandia.gov]

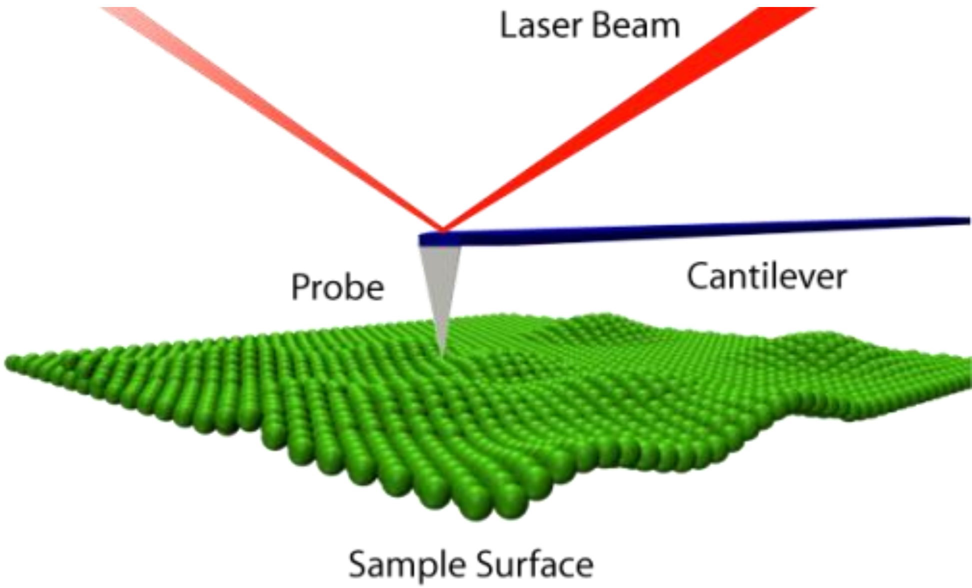


The Outcomes

Surface Acoustic Wave (SAW) Sensors



Atomic Force Microscope (AFM)



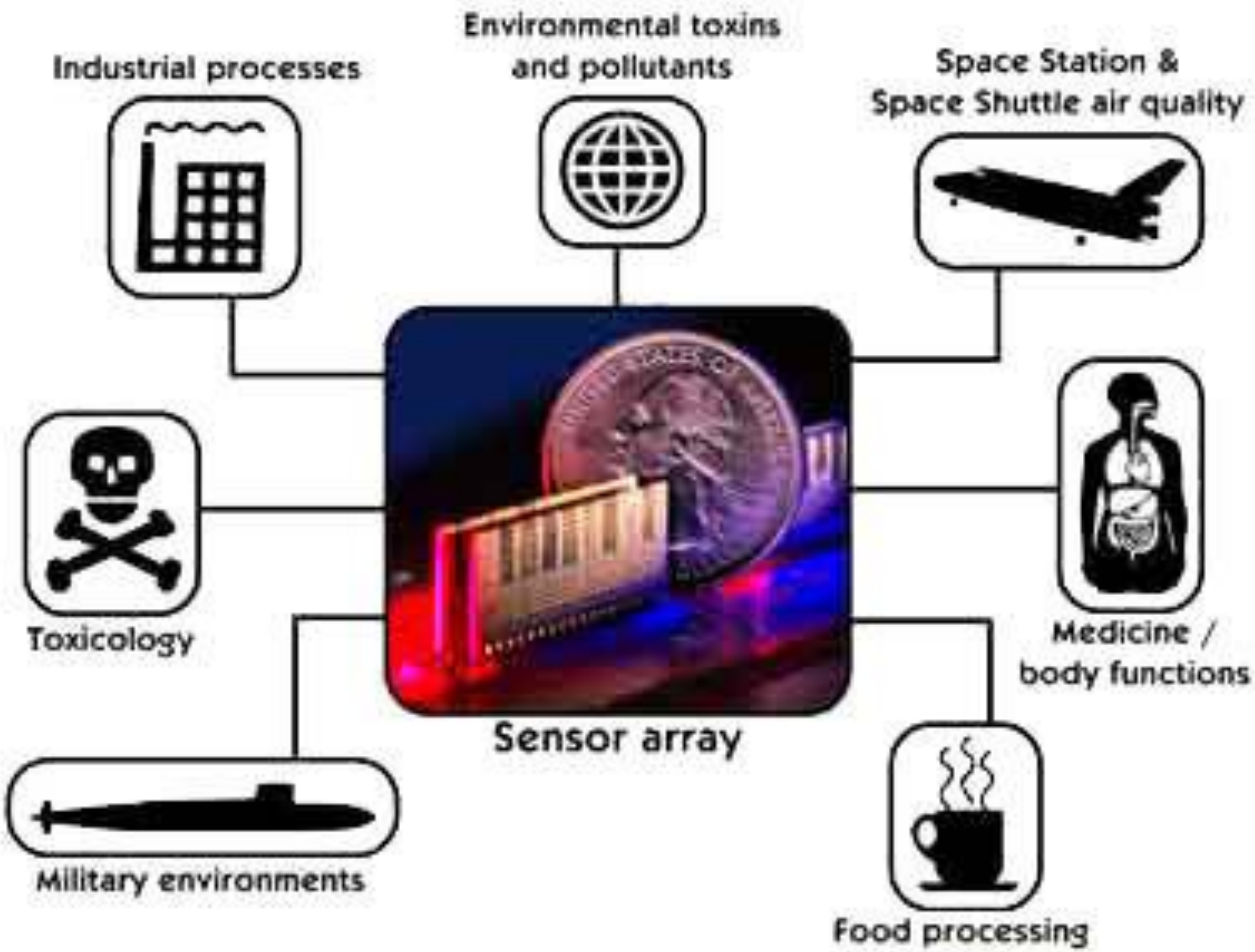
Question

Where is all of this technology headed?

What are some of the future possibilities using microsystems technologies?

Where is microsystems technology headed?

- Electronic nose or Enose *[graphic courtesy of NASA]*



Where is microsystems technology headed?

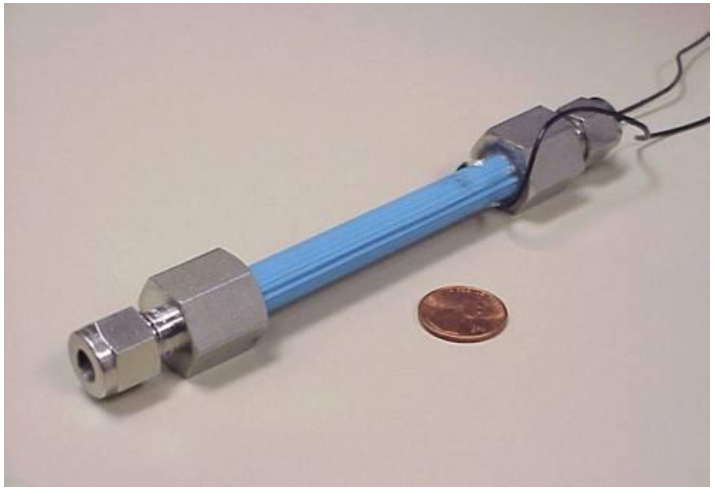
- ENose

The Enose used to ensure air quality in the space station.
[Courtesy of NASA]

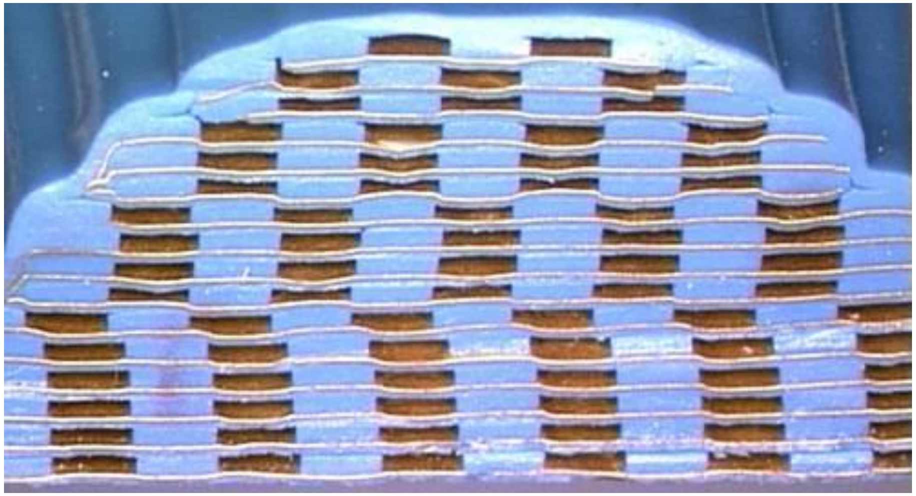
Cyborgs – Robotic bugs with Enose MEMS that can fly into unapproachable environments.

Microfluidics

- Current microfluidic technology is limited to small volumes (micro and nanoliters).
- Research is being conducted on higher flow microtechnology.



High Flow Concentrator



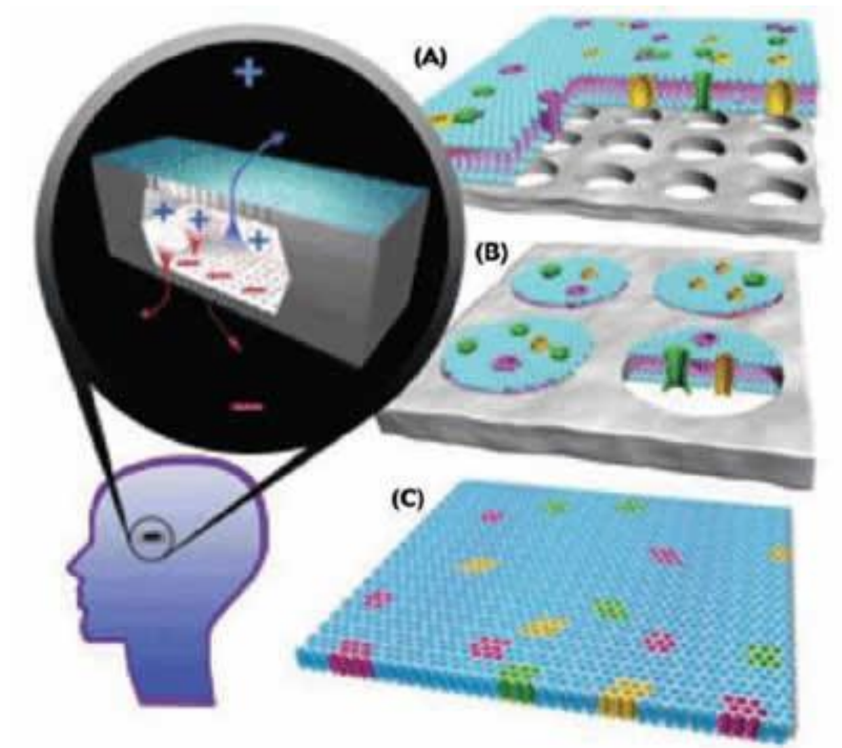
Cross-section of High-Flow Concentrator

BioMems / Microfluidics @ Sandia National Laboratories (SNL)

[Images courtesy of SNL]

Energy Efficiency and Supply

- In vivo batteries for in vivo medical devices
- Inertial sensors to indicate the lack of motion causing devices to powerdown.
- Energy harvesting – MEMS transducers that “harvest” energy of one type (e.g., vibration or heat) and convert to another form of energy (e.g., electrical).



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

Question

What are some of the challenges that microsystem technologies face in moving forward?

- Participants' Poll
  a. Lower power consumption
  b. User interface
  c. Multi function devices (sensors, actuators, power supplies)
  d. All of the above

Question

What are some of the challenges that microsystem technologies face in moving forward?

– Participants' Poll

a. Lower power consumption
b. User interface
c. Multi function devices (sensors, actuators, power supplies)
d. All of the above

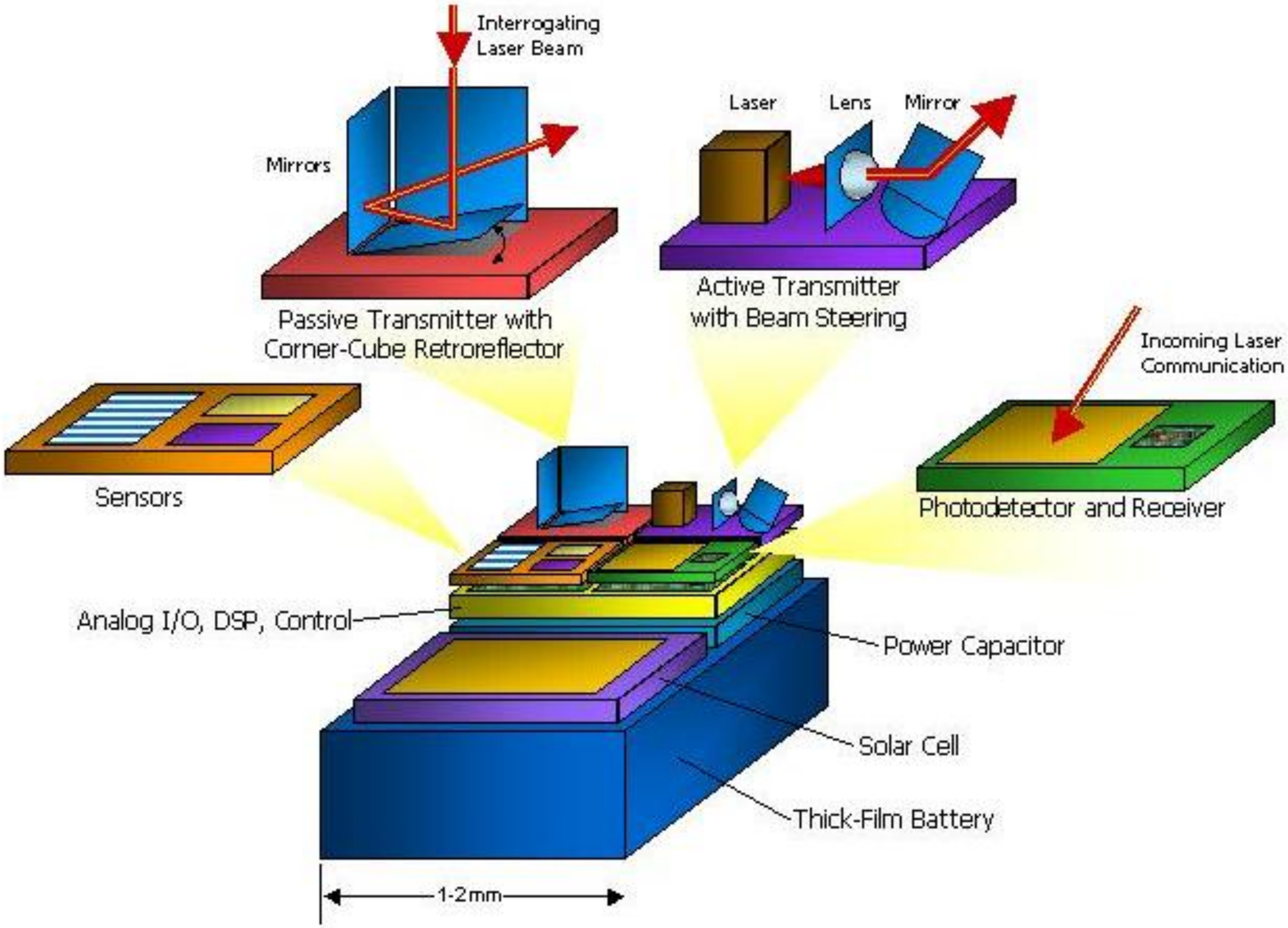
- Answer: **d, All of the above**

Challenges in Microsystem Technologies

- Packaging (e.g., size, durable, biocompatible, interface)
- High volume production
- Smaller die
- CMOS and MEMS fabrication integration as die get smaller
- Batteries (i.e. delivering power in a small packing for a long time)
- Integration of multiple sensors and MEMS devices in the same chip and/or package.
- Improved efficiency of RF and microwave communication systems
- Availability and biocompatibility of implantable devices for measuring pressures, in vivo chemical analysis, drug delivery

Dr. Kurt Peterson, an expert in the field of microsystems technology. MEMS industry overview: the past, the present and the future. MEMS Investor Journal

Challenges



Smart dust (sensors) impeded into the physical components (e.g., roads, bridges, buildings, aircraft). *Source: [Smart Dust? Not Quite, but We're Getting There](). The New York Times. January 2010. [Image courtesy of Kristofer S. J. Pister (University of California, Berkeley)]*

The MEMS Market

- In 2005 MEMS based products had a value of $8 billion.
  - 40% for sensors
  - 60% for products that included micromachined features, such as ink jet print heads, catheters, and RF IC chips with embedded inductors.
- Growth projections
  - $40 billion in 2015
  - $200 billion in 2025
  - Devices such as disposable chips for performing assays on blood and tissue samples, integrated optical switching and processing chips, and various RF communication and remote sensing products.

The Future of MEMS. Dr. Thomas F. Marinis, Draper Laboratory.

The Future of MEMS. Howard Baldwin, January, 2009. Design News.

What Does this Growth Mean

- We need more technicians!
  - Research, design, fabrication, process, and engineering

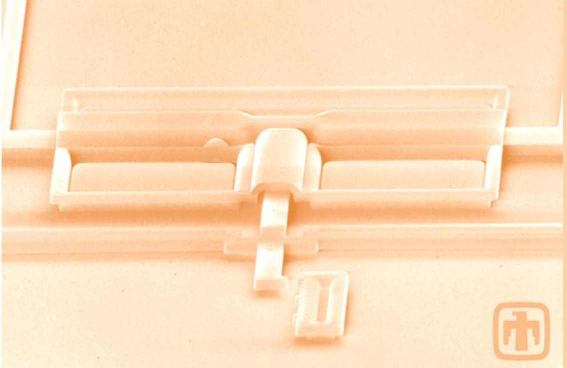
- Are you curious?
- Do you like to know how things work?
- Are you interested in how things are made?
- Do the wonders of new technologies excite you?

Recap

This webinar has extracted information from the following SCME Learning Modules.

- MEMS Applications
- BioMEMS Applications
- Comparison of Scale – Macro, Micro, and Nano
- History of MEMS

- All Learning Modules can be found at the www.scme-nm.org.
  - Participant Guides can be downloaded by students and the general public.
  - Instructor Guides and presentations can be downloaded by registered users only.



Thank You For Joining Us

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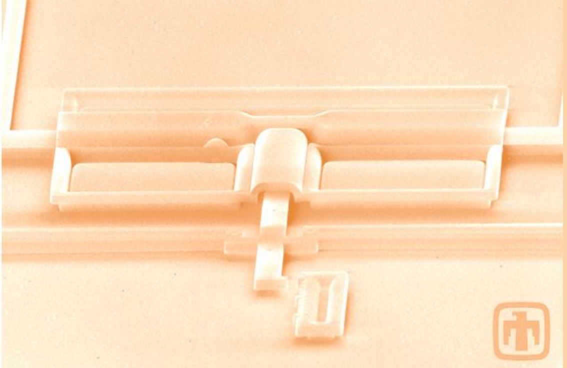


How Can We Serve You Better?

Southwest Center for Microsystems Education

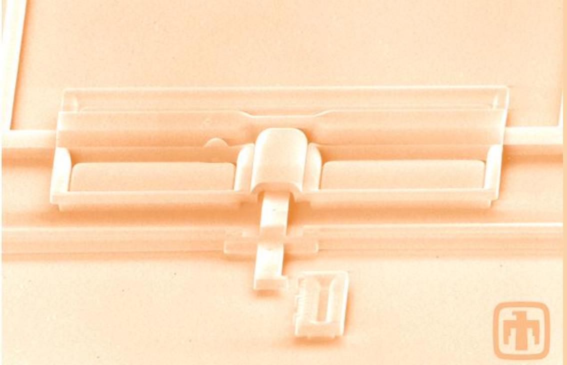
Please take 1 minute to provide your feedback and suggestions

https://www.zoomerang.com/Survey/WEB22DFNGEYR4W

Webinar Resources

To access this webinar recording, slides, and handout, please visit

www.scme-nm.org



SCME Upcoming Webinars

Friday, December 2, 2011 MEMS 102: How do Microsystems work?

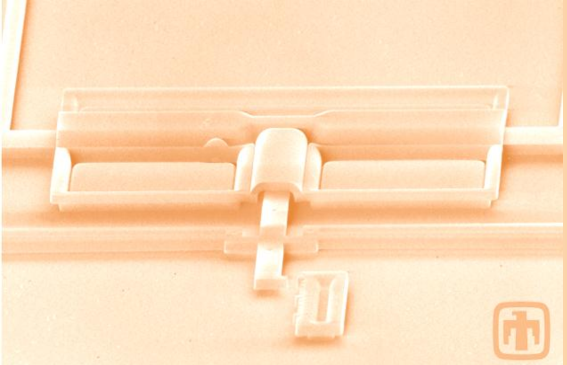
Friday, January 20, 2012 MEMS 103: Biomedical Applications of BioMEMS

Friday, March 2, 2012 MEMS 201: Topics on Microsystems Materials – Crystal Structures

Thursday, April 12, 2012 MEMS 202: Standard Micromachining Techniques

Thursday, May 3, 2012 MEMS 203: Making a MicroPressure Sensor

All Webinars @ 1 PM ET



It was Fun!

Thank you for attending this SCME Webinar

MEMS 101

Introduction to Microsystems