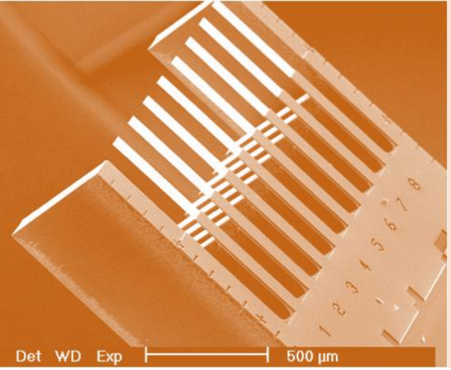
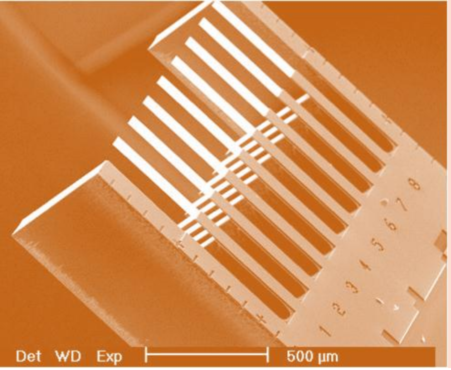


MEMS 102
How do Microsystems Work?

Presented by
Southwest Center for
Microsystems Education
-SCME-

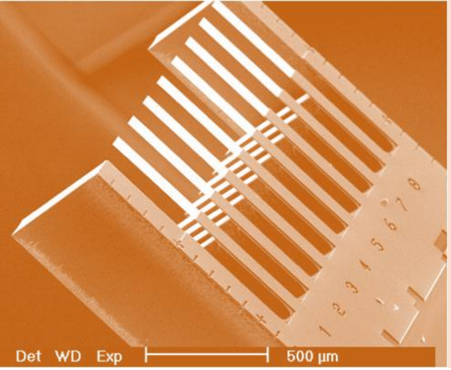


SCME
Southwest Center for Microsystems Education

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

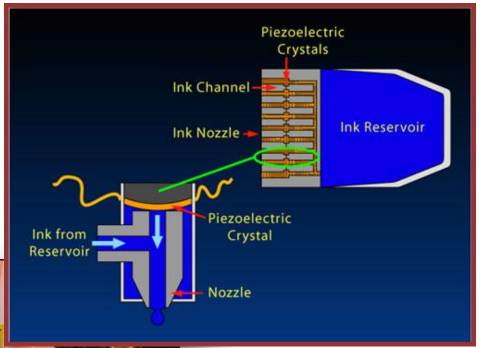
Instructional Designer, SCME and retired Chair for the Manufacturing Technology Program – Central New Mexico Community College

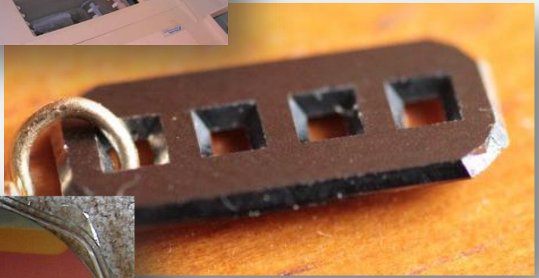
Objectives for Today

- What can SCME do for you?
- What do Microsystems do?
- What are Transducers and how do they work?
- What are Sensors and how do they work?
- What are Actuators and how do they work?

Educational Materials

Southwest Center for Microsystems Education





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

Professional Development

Southwest Center for Microsystems Education

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

MicroElectroMechanical Systems (MEMS)

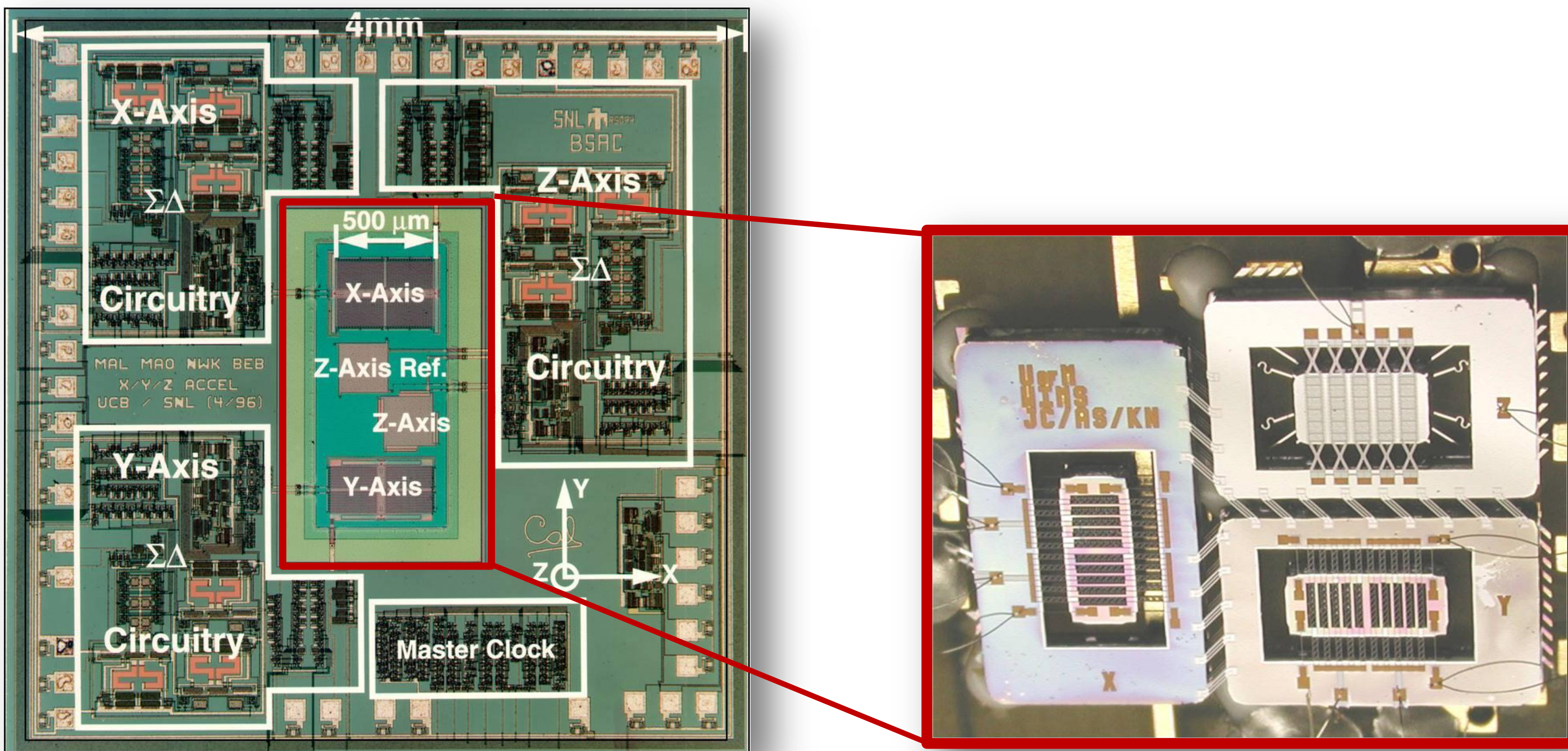
MEMS, Microsystems, and Microsystems Technologies (MST) all refer to a set of microsize systems and micro-size components.

In our first webinar – MEMS 101 – we covered a variety of MEMS applications in several fields:

- Consumer products
- Biomedical
- Environmental
- Microfluidics
- Micro-optics
- Communications
- Semiconductors

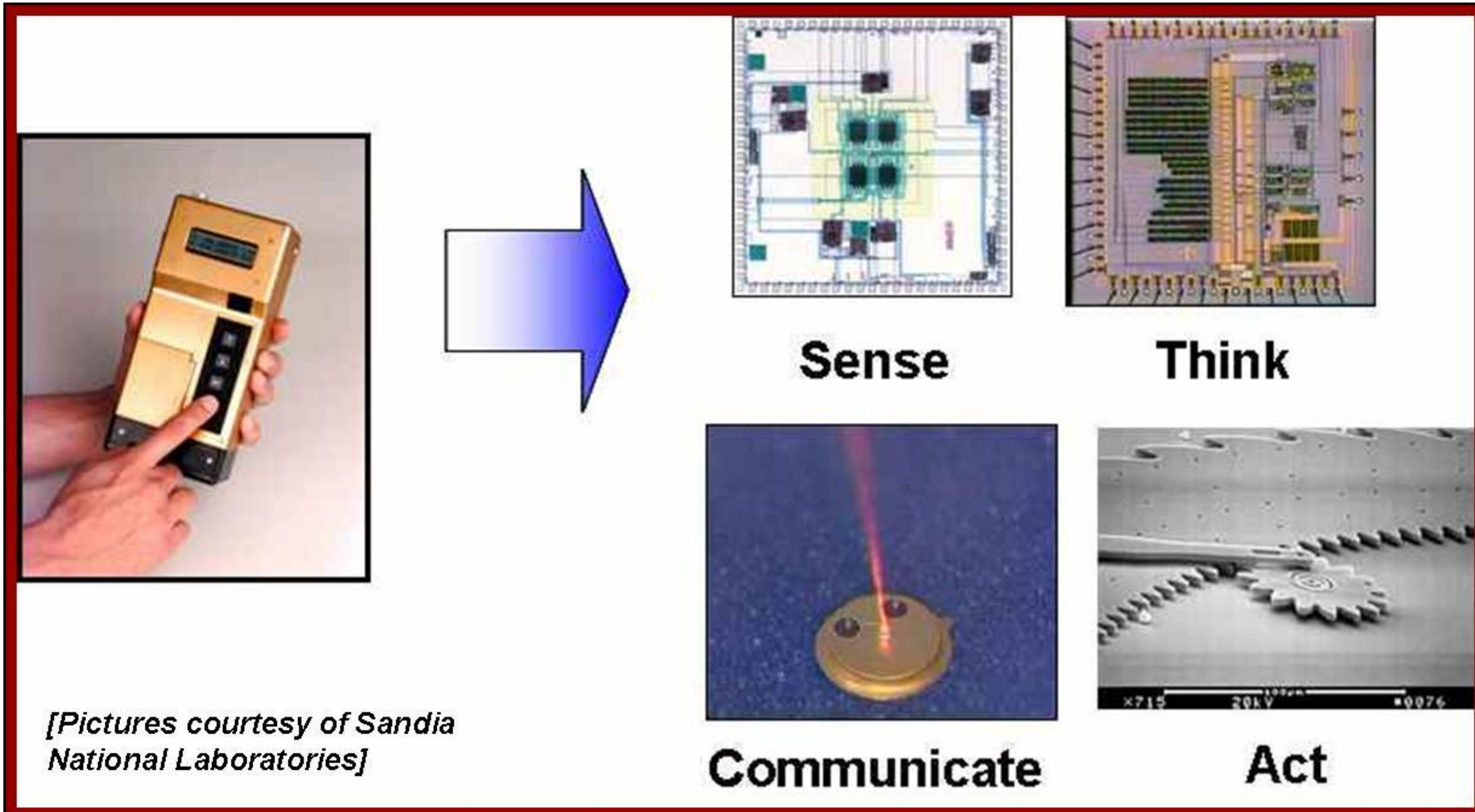
MEMS Components

In this presentation we will be discussing MEMS components – the transducers, sensors and actuators found in the microsystem.



What do MEMS Do?

MEMS (MicroElectroMechanical Systems) are devices that can sense, think, communicate, and act.



[Pictures courtesy of Sandia National Laboratories]

Transducers, Sensors, and Actuators

Transducers change one form of energy to another form of energy.

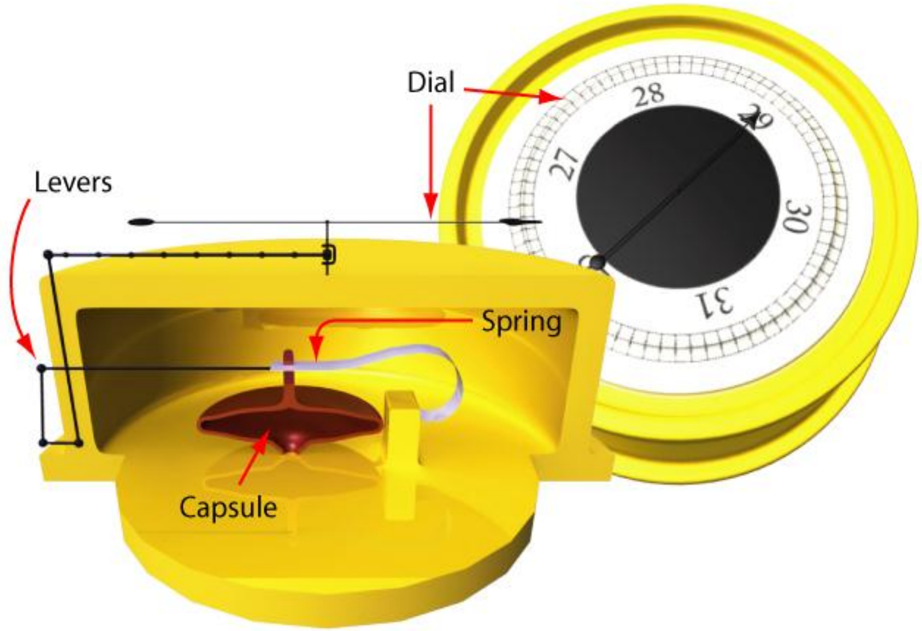
Light bulbs

Microphones

Motors and Generators

Transducers, Sensors, and Actuators

- Sensors receive signals and respond to them.
- Sensors quantify or measure the amount of change.

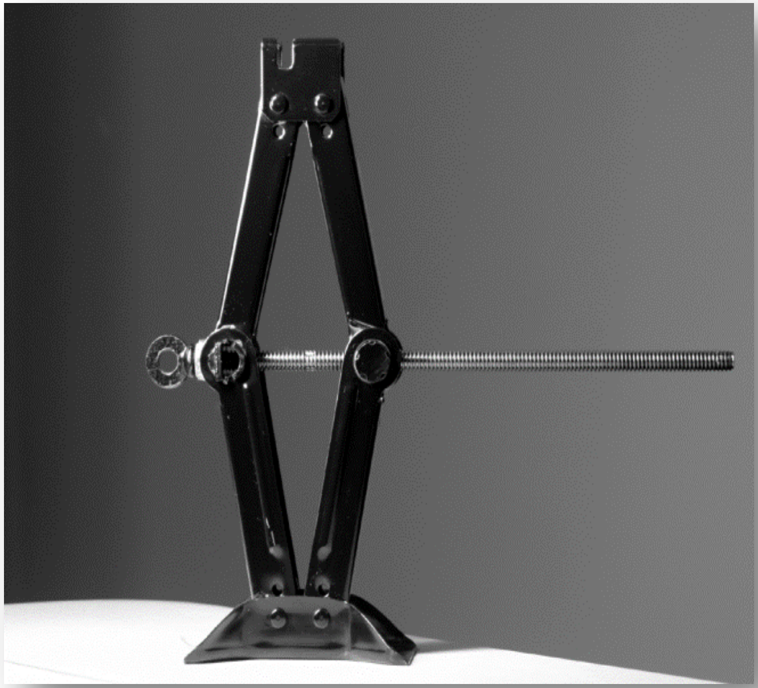


Aneroid Barometer
Detects and measures changes in atmospheric pressure

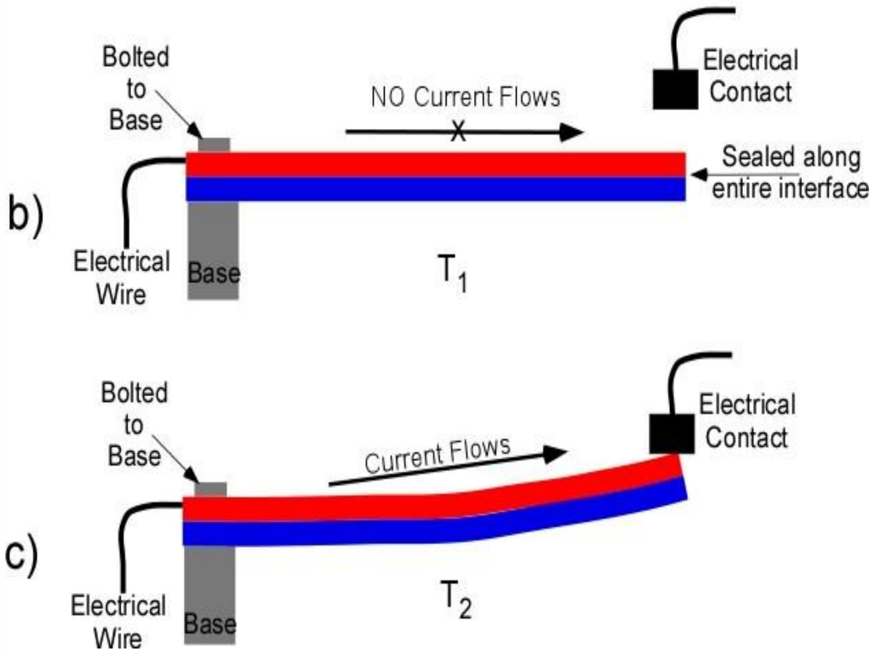
Gas or Chemical Sensors
Detects and measures the amount of carbon dioxide, oxygen, or another gas or gases.

Transducers, Sensors, and Actuators

Actuators actuate or move something



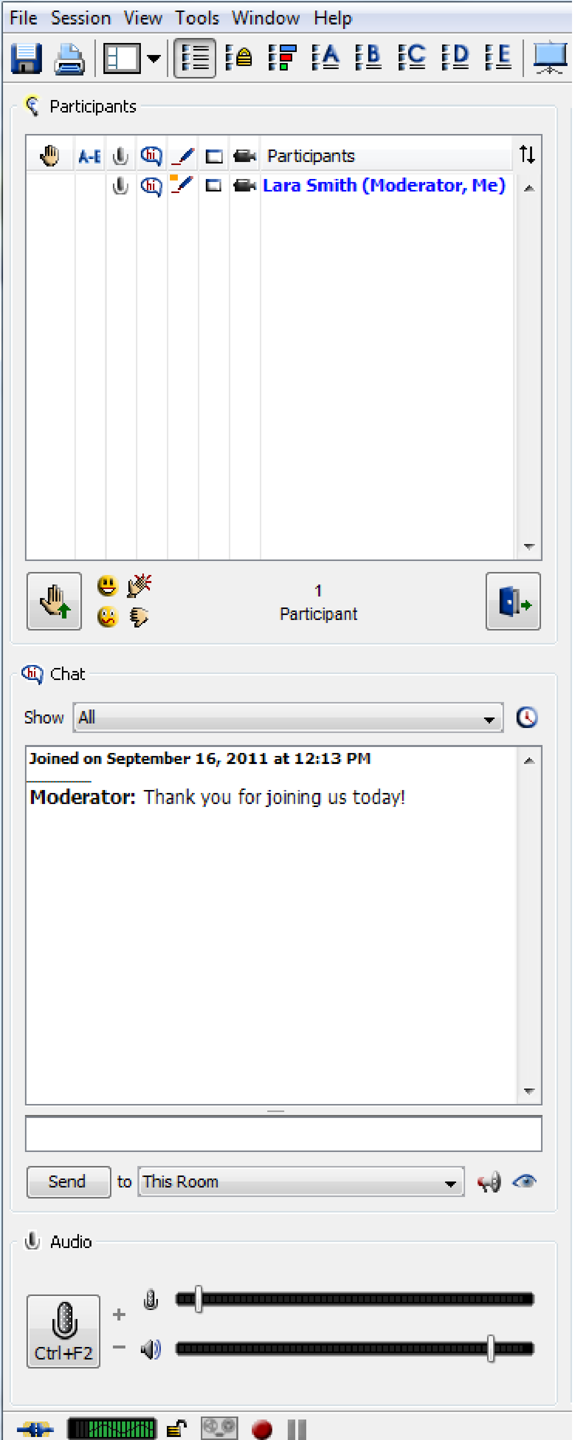
Screw Jack



Switches such as this Bimetallic Switch

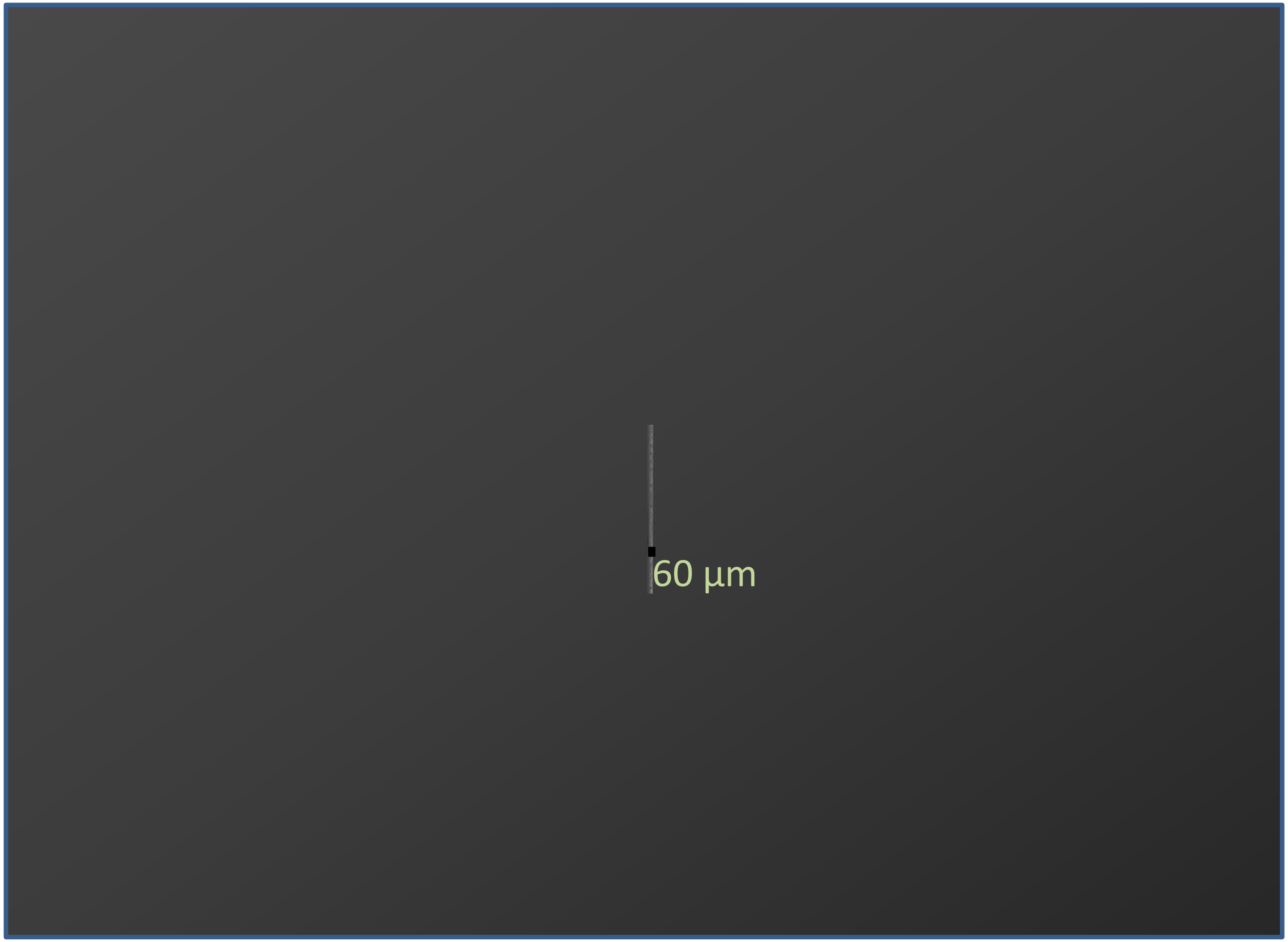
Question?

What are some transducers, sensors and actuators that you are familiar with?



? Type answers into the chat box

Think Small!



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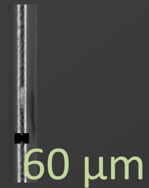

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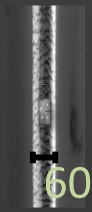

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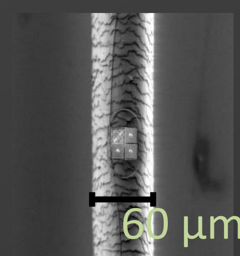

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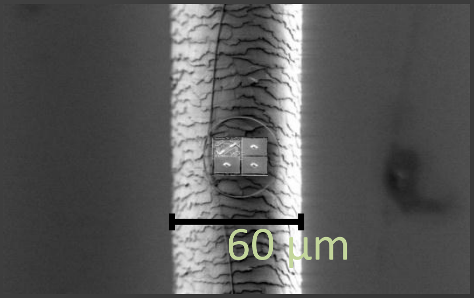

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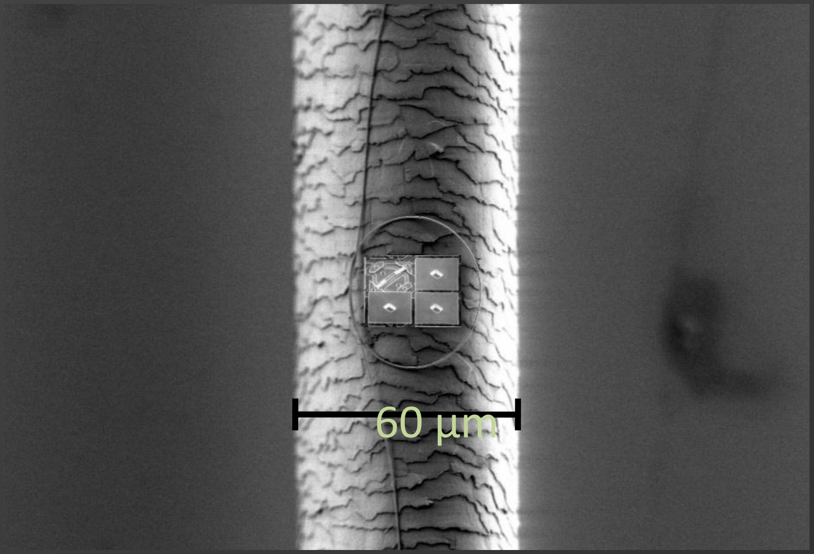

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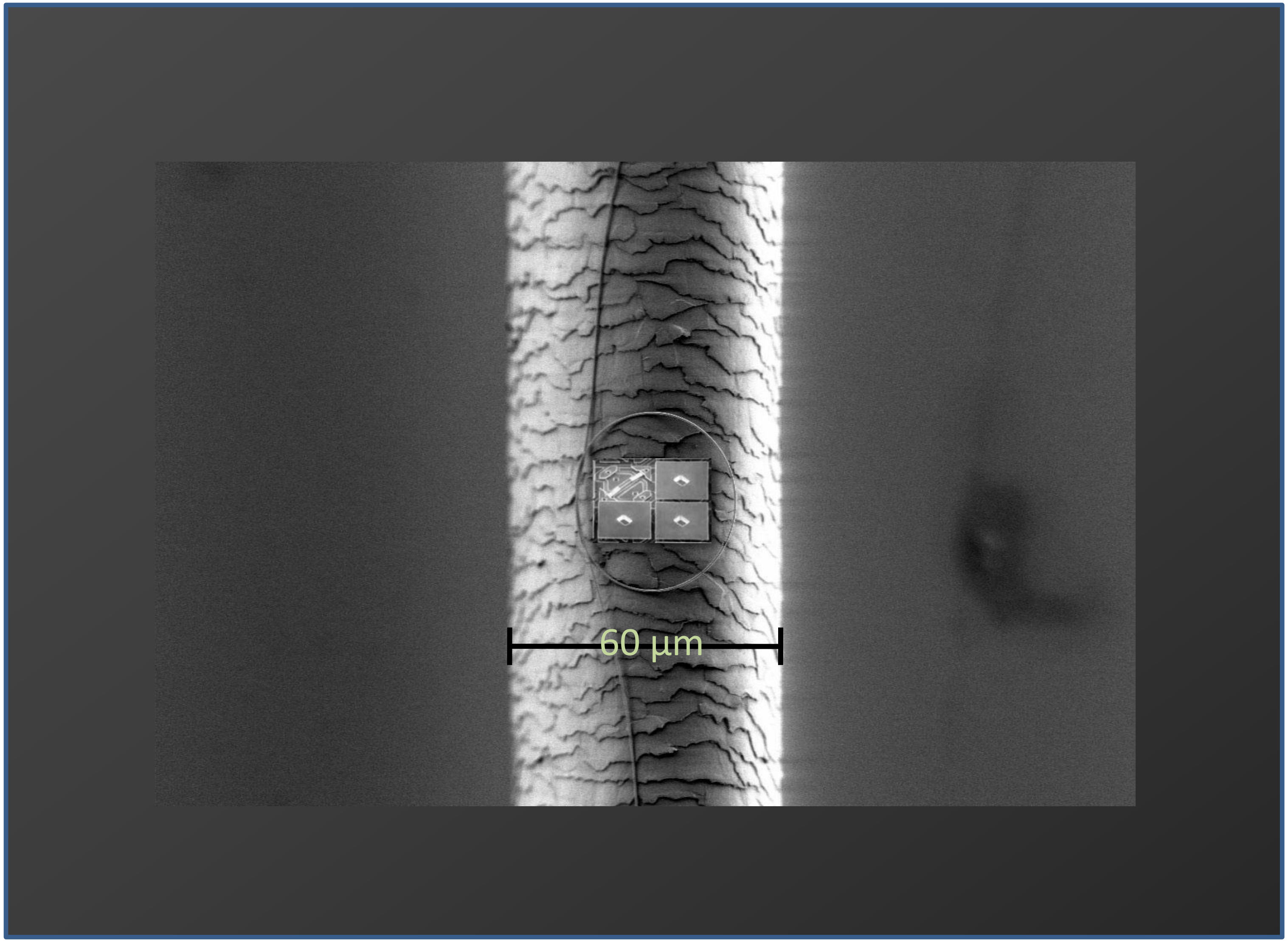

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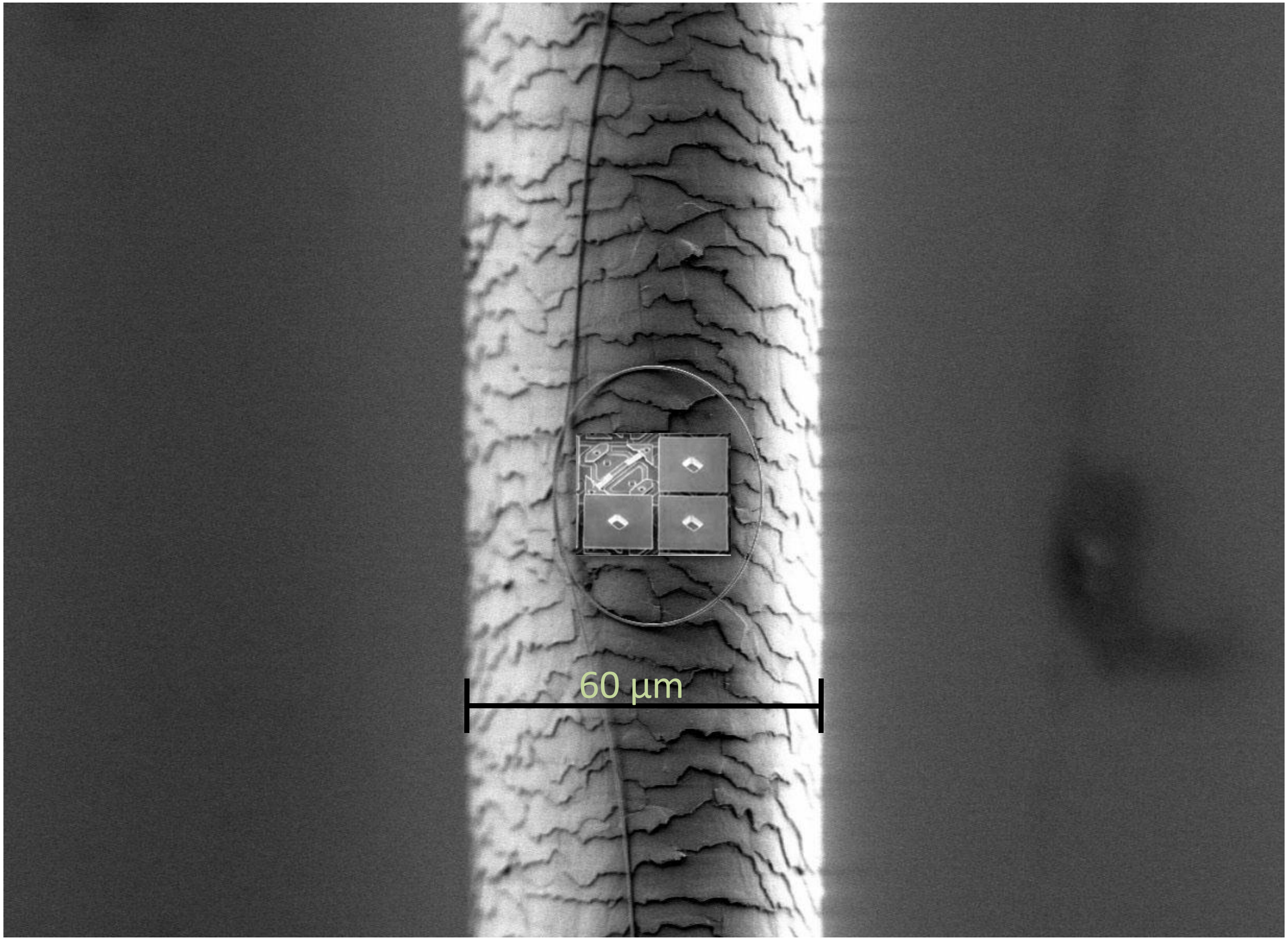
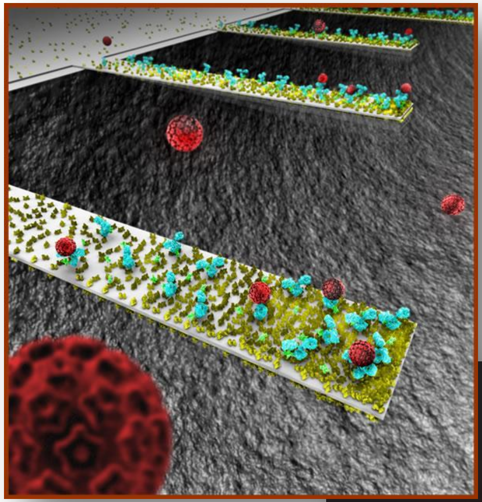
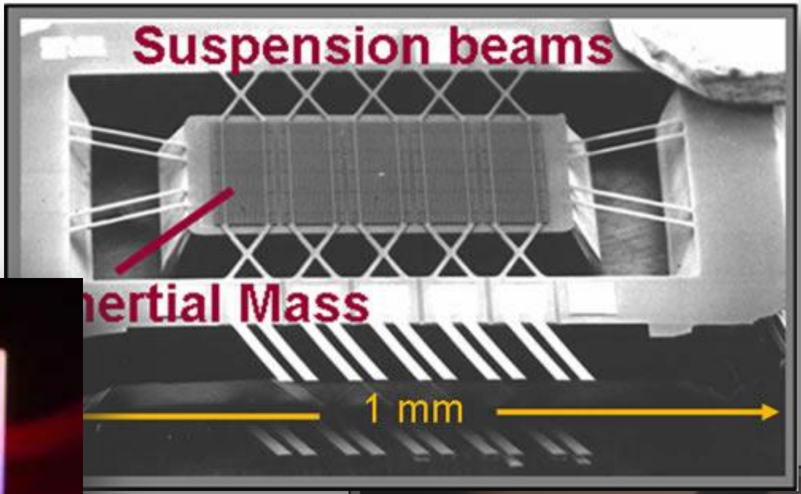


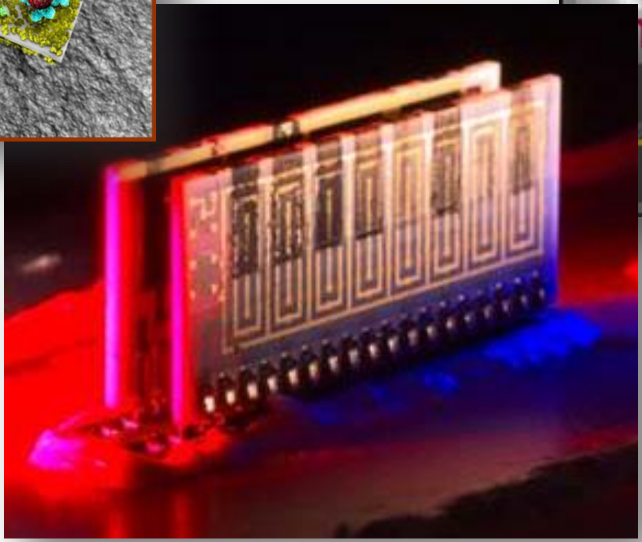
Micro-Transducers and Sensors

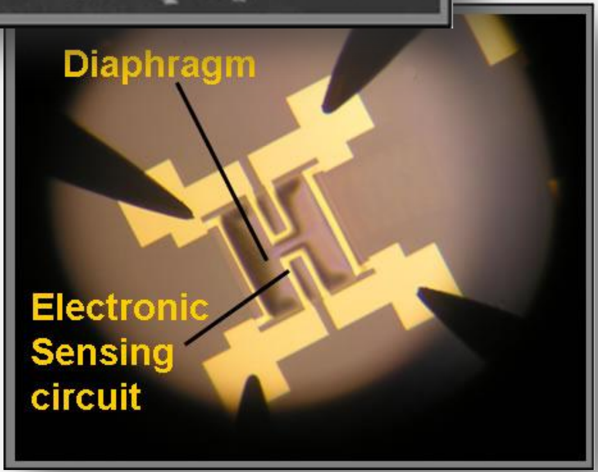


Cantilever

Accelerometer







Electronic Nose

Pressure Sensor

Chemical Sensors

- Microchemical Sensors are either an array of cantilevers or a single cantilever
- Applications for chemical sensor arrays
  - Gas leak detectors
  - Detection of chemicals
  - Biosensors
  - Sensors for DNA hybridization and Protein binding
  - pH sensors
  - Glucose sensors
  - Biomolecular analysis
  - Charged-particle flux detector
  - Various volatile organic compounds

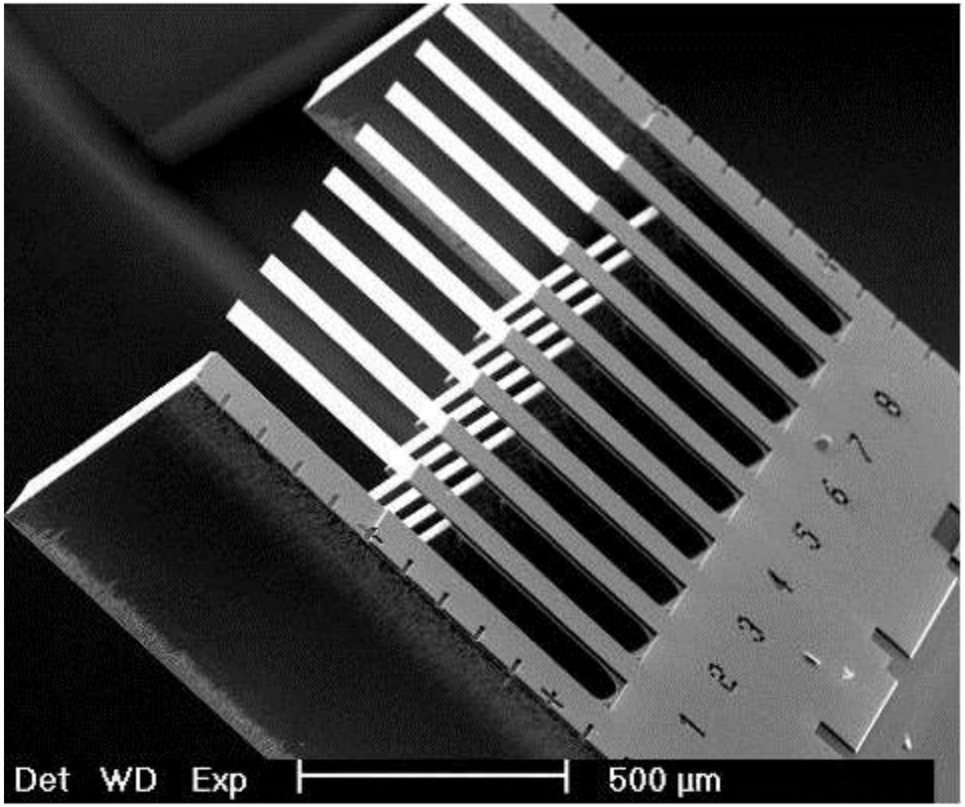
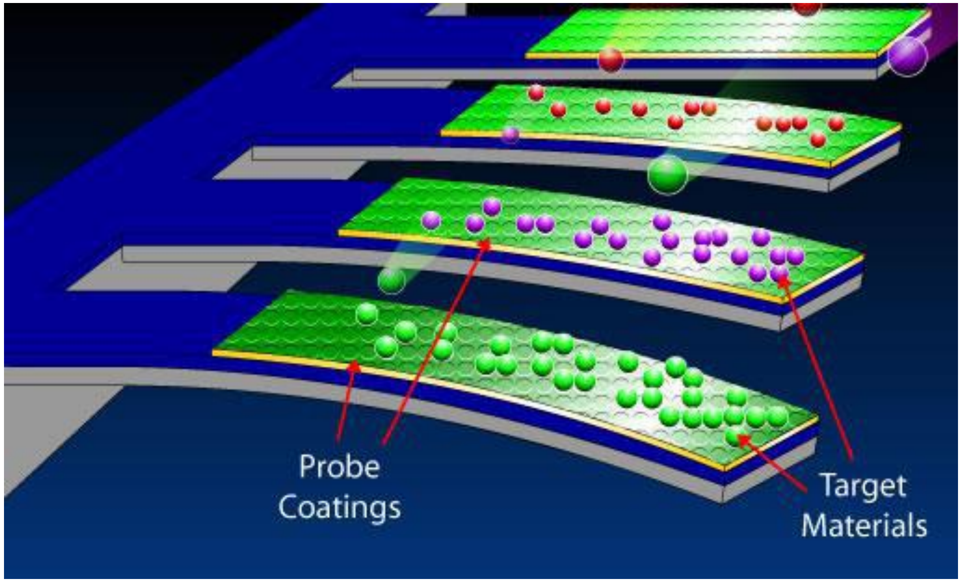


Image courtesy of Dr. Christoph Gerber, Institute of Physics, University of Basel

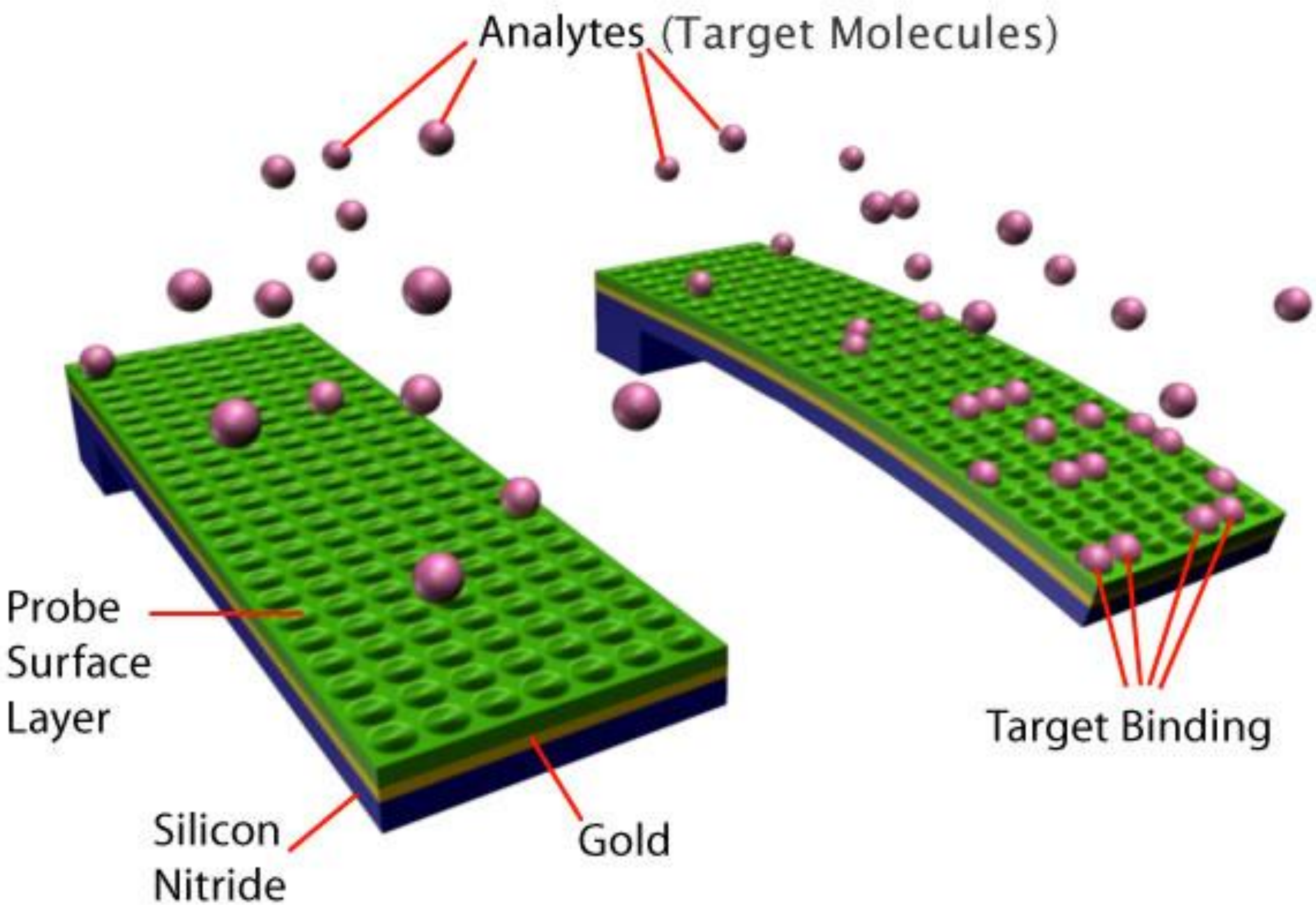
Chemical Sensor Arrays (CSAs)

- Detect & measure the amount of a specific substance in a sample
- Can detect several substances simulataneously
- CSAs are chemically discriminating

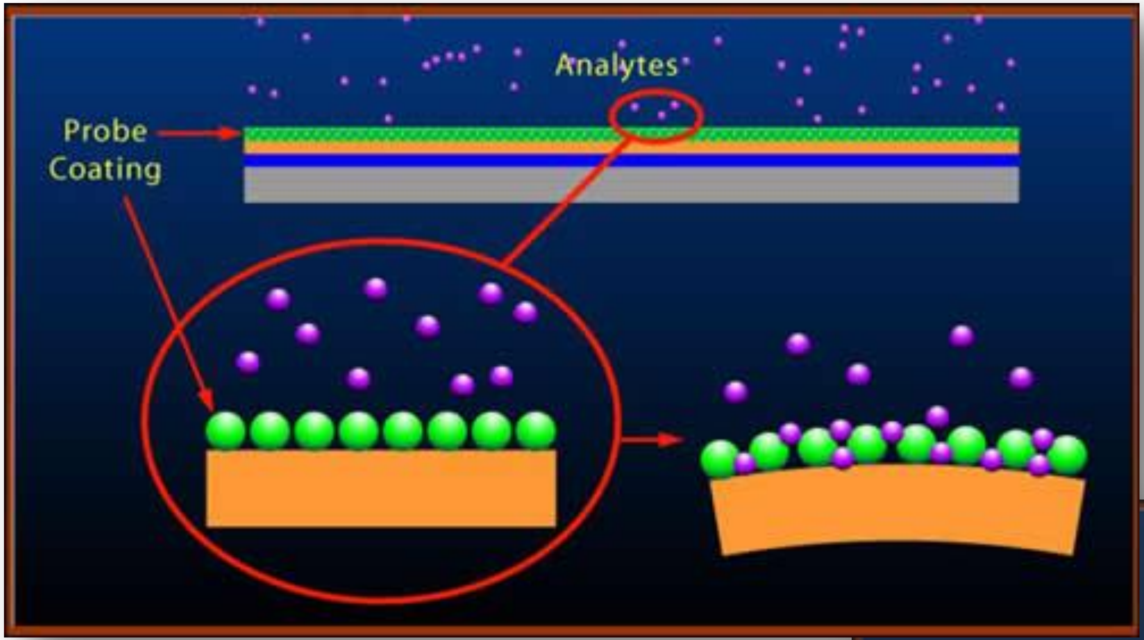


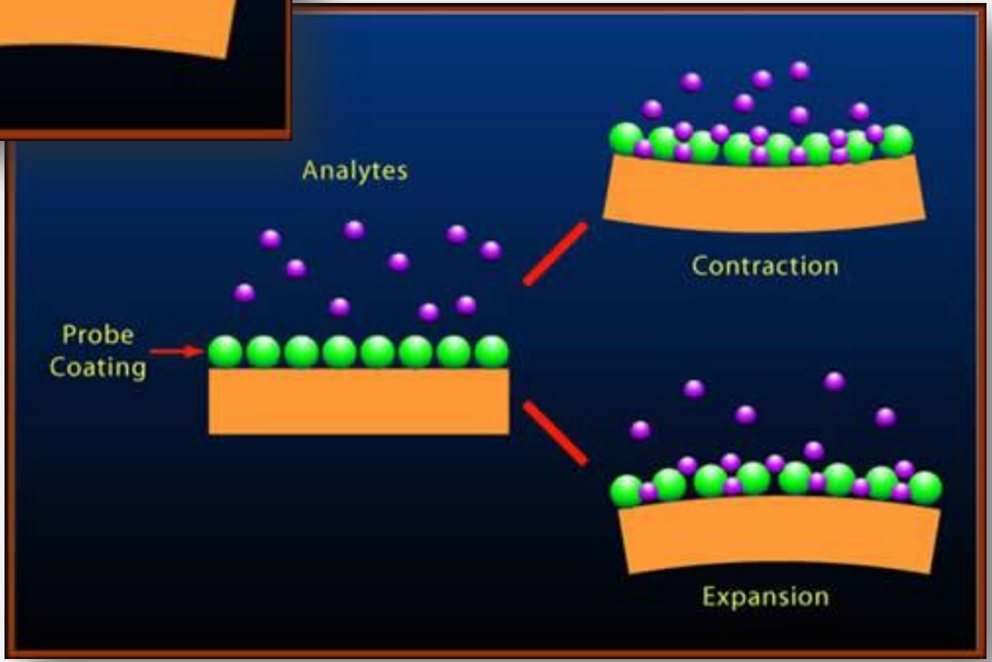
- Each cantilever is coated with a chemically sensitive probe coating
- By designing a CSA with a different probe coating on each cantilever, a CSA can be used to detect several different substances within the same sample.

Surface Stress Chemical Sensors



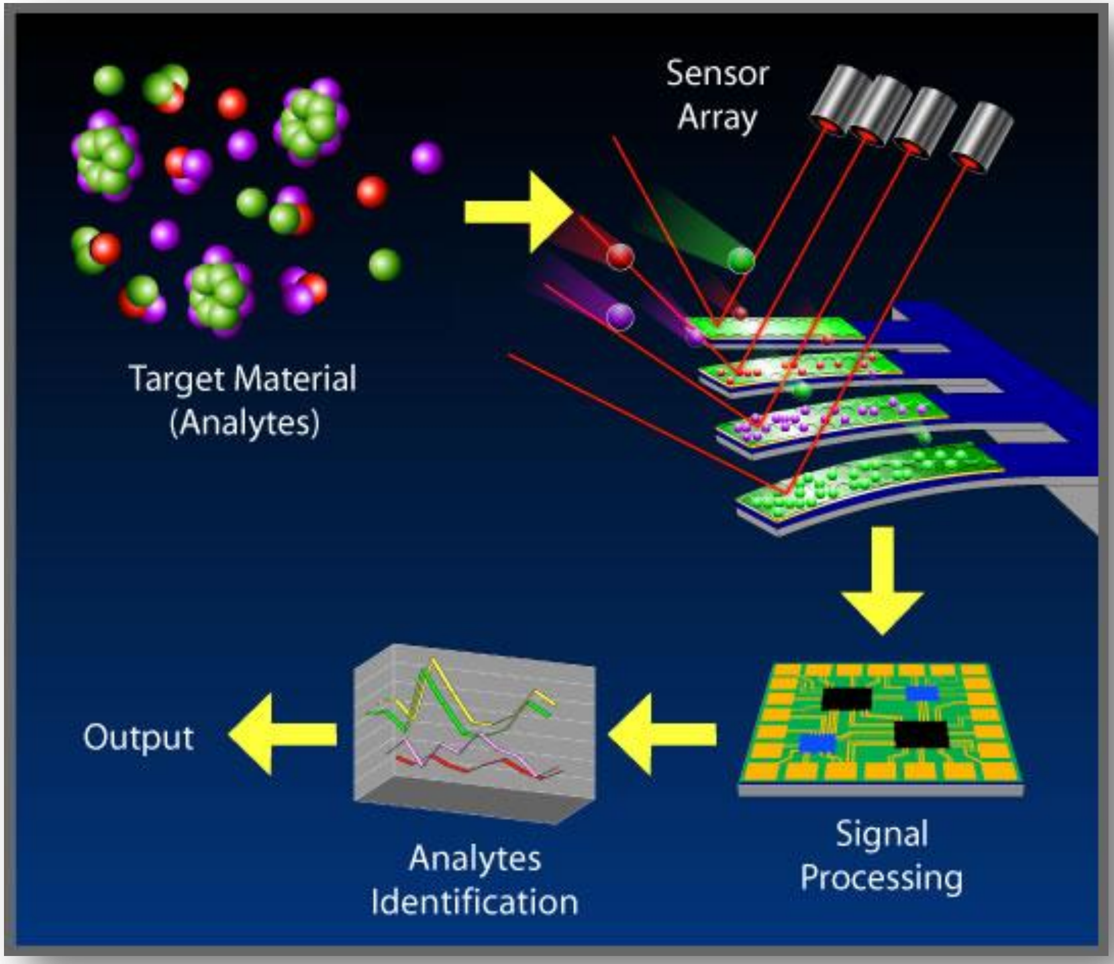
Surface Stress Chemical Sensors





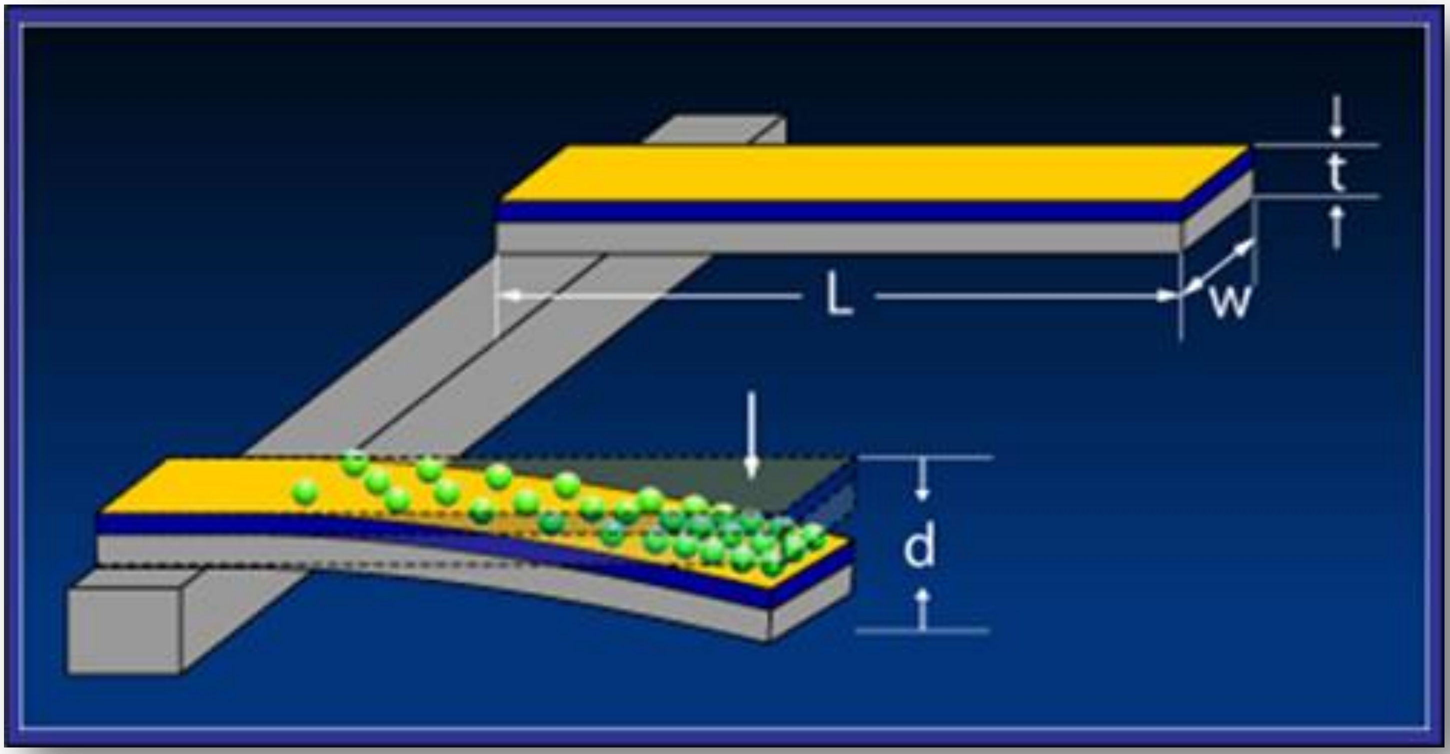
Chemical Sensor Arrays (CSAs)

- When analytes bind to the probe coatings, a change in the cantilevers' mechanical or electrical properties occurs

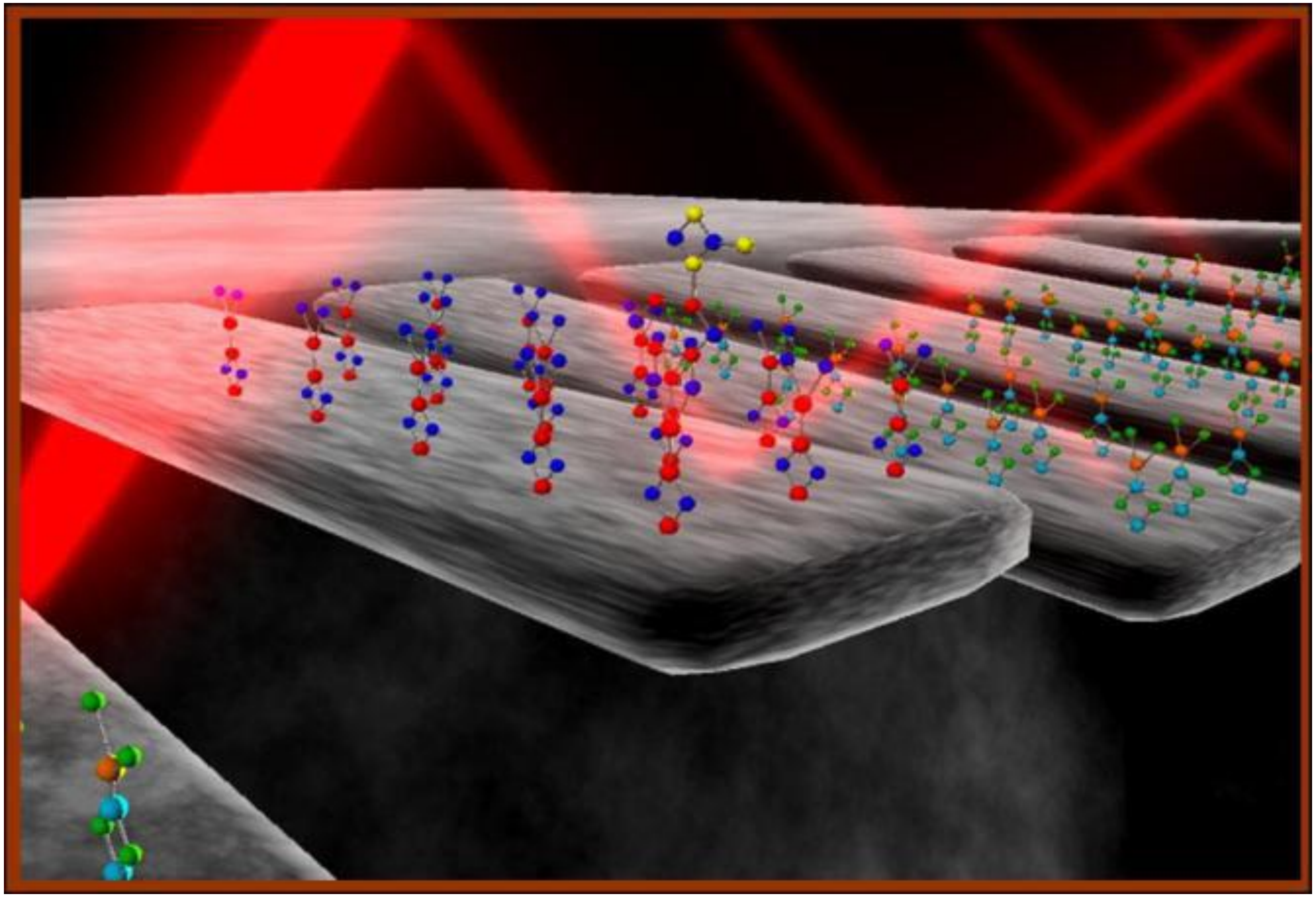


Mass Sensitive Chemical Sensor

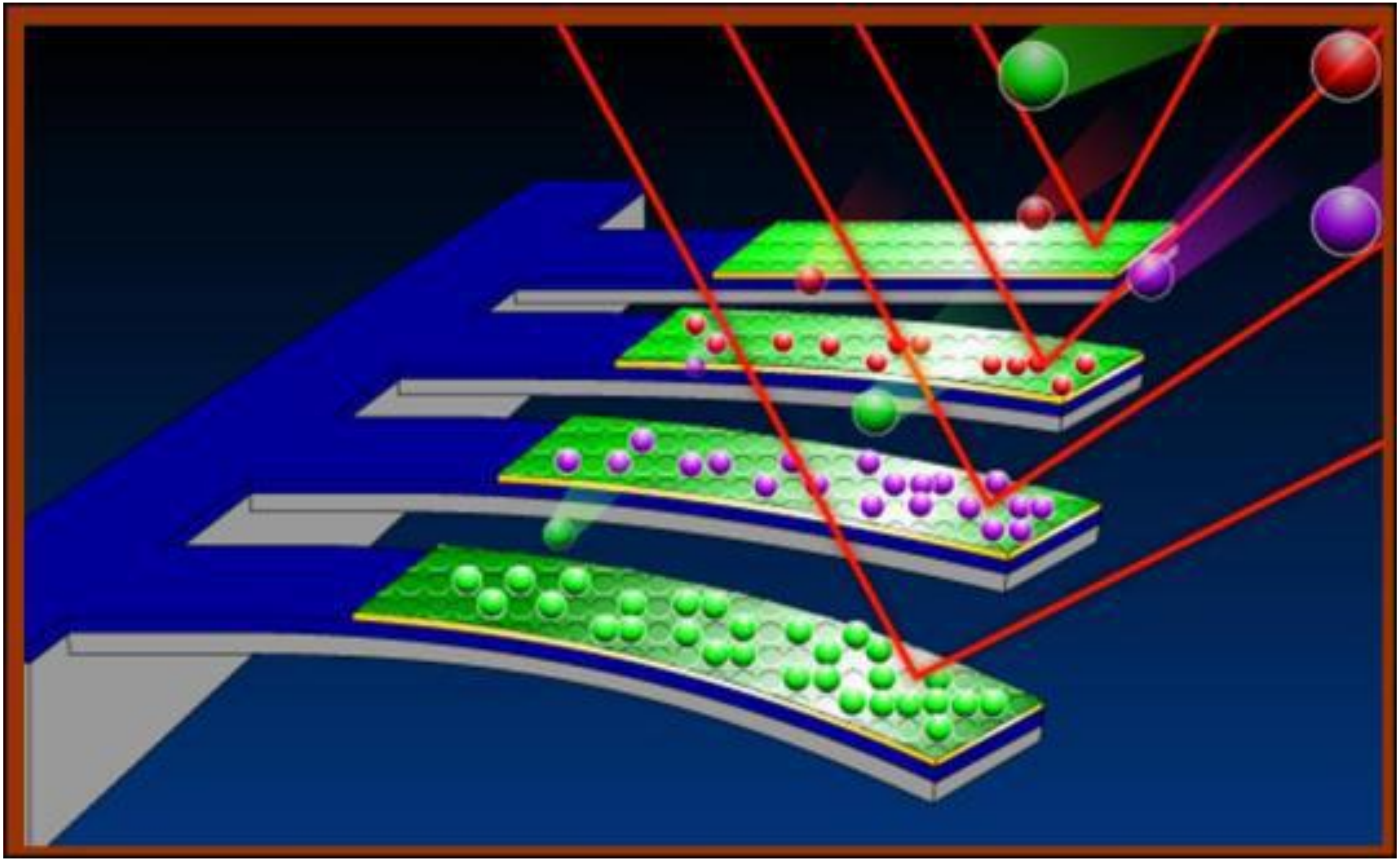
- When a cantilever sensor is mass sensitive



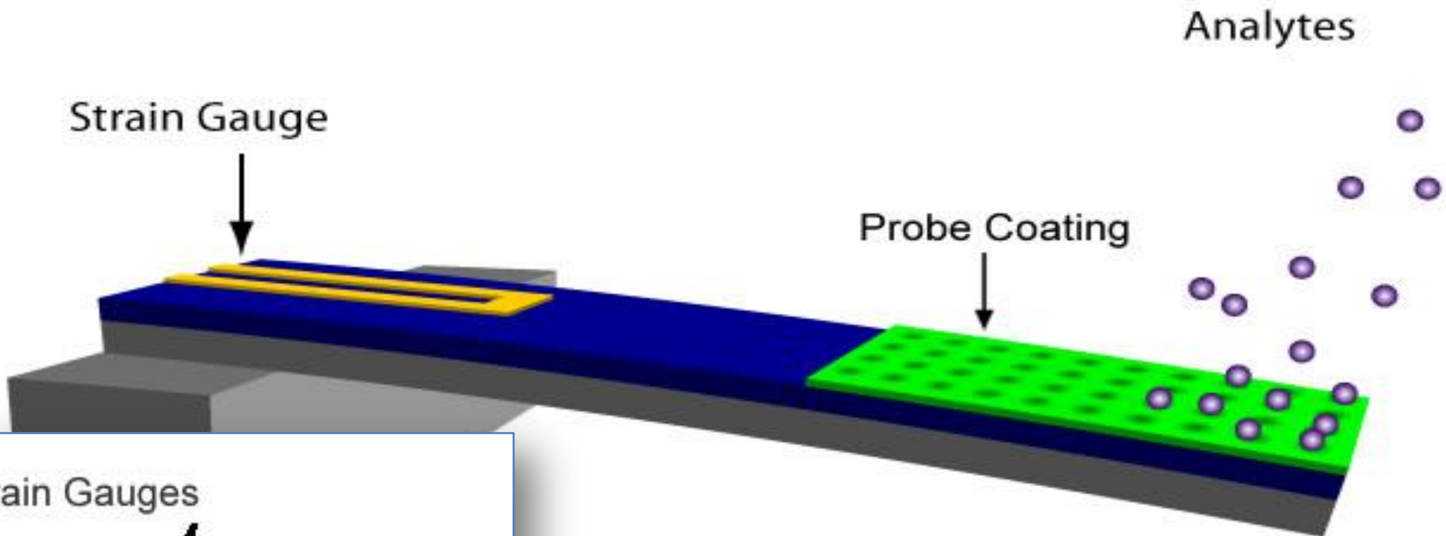
Mass Sensitive Chemical Sensor

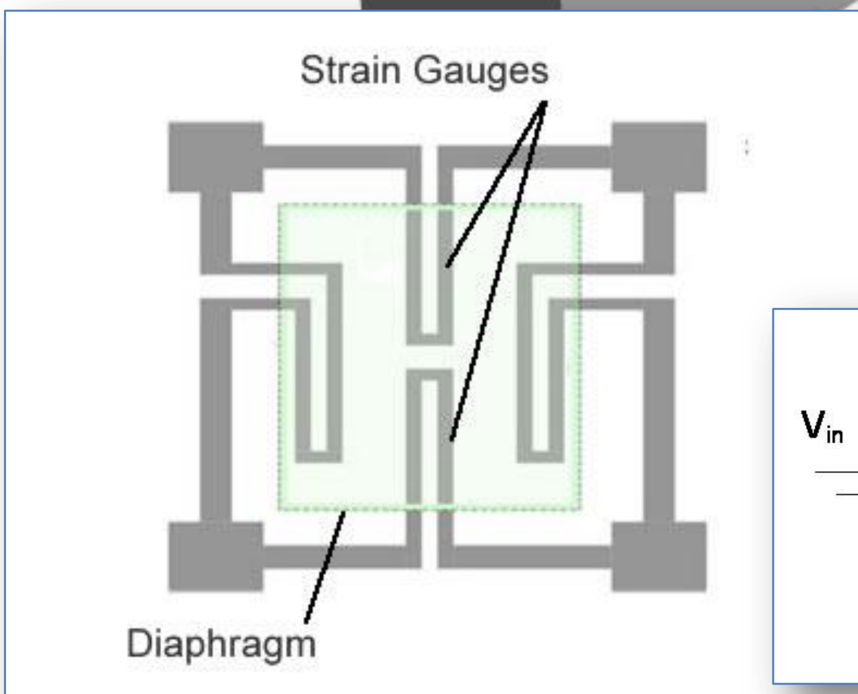


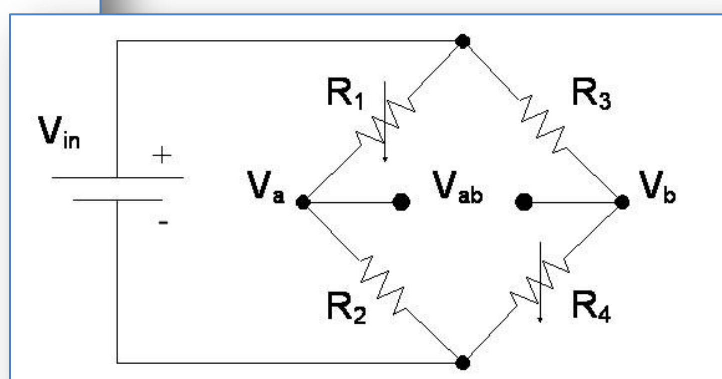
Measuring Displacement – Δ in Angular Deflection



Measuring Displacement – Δ in Resistance







Question - Poll

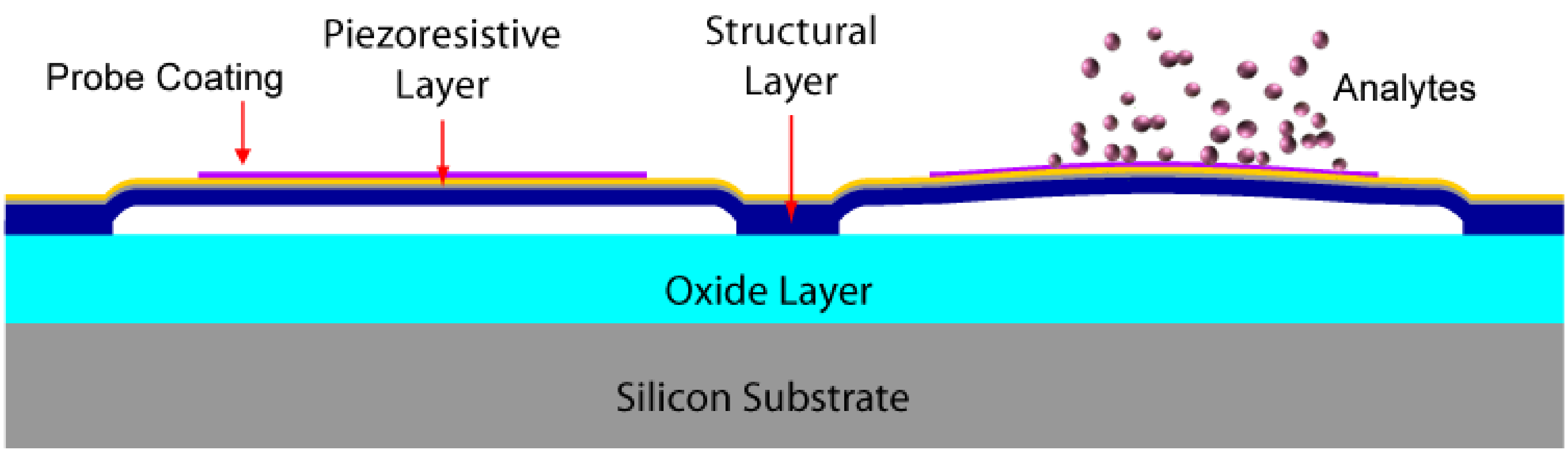
Cantilevers operating in the Dynamic mode use which of the following cantilever properties for detection

A. Surface stress
B. Angle of deflection
C. Resonant frequency
D. Weight of the analyte
E. C and D

Answer: C

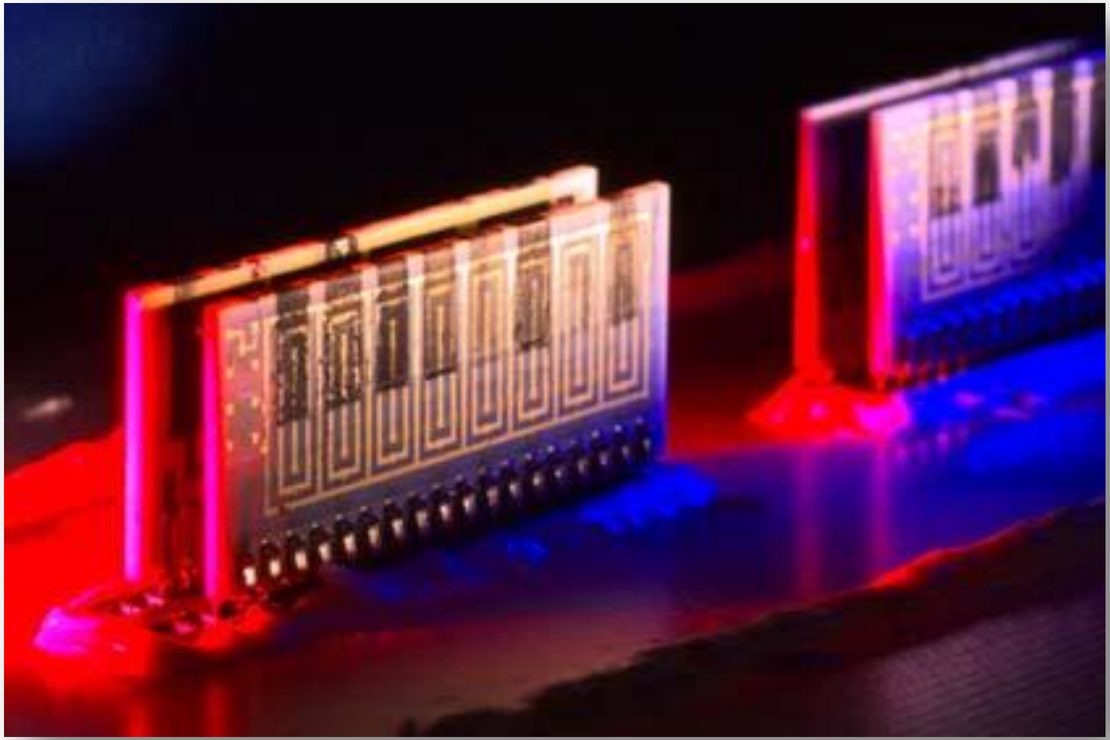
Gas Sensing Devices

This gas sensing device uses a piezoresistive layer and probe coating fabricated on top of a structural layer of polysilicon.
The probe coating is designed to detect and latch on to a specific molecules or “analytes”.
Several “probes” can be fabricated to form an array able to detect hundred’s of different gas molecules simultaneously.



Electronic Nose (Enose)

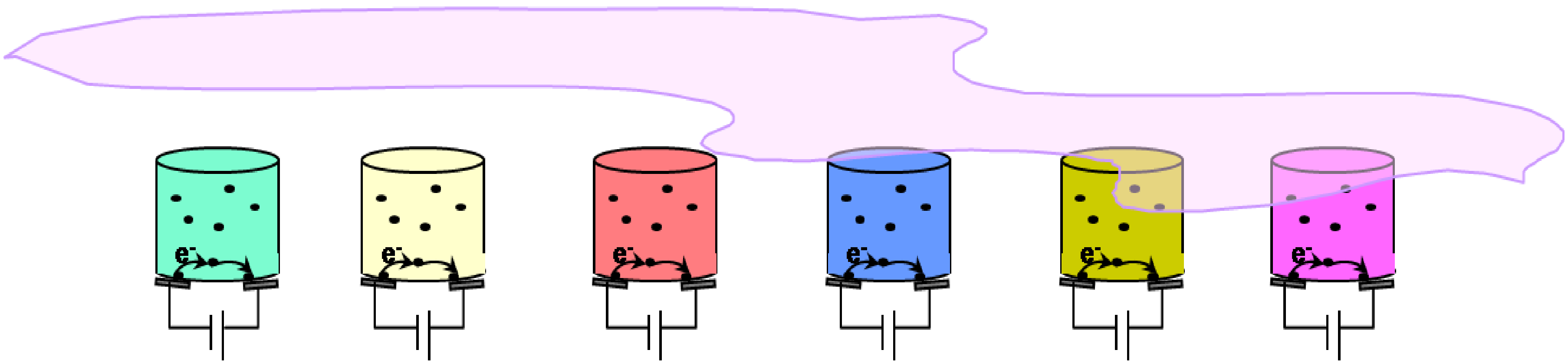
An Enose is a microdevice that uses sensing components to detect specific gas molecules in a sample or in the surrounding environment. Like our noses, an enose can detect multiple “smells” simultaneously.



This image, courtesy of NASA, shows an array of electrodes with each electrode acting as a transducer that can detect a specific gas or working together, can identify an “odor”.

Electronic Nose (Enose) – Polymer Films

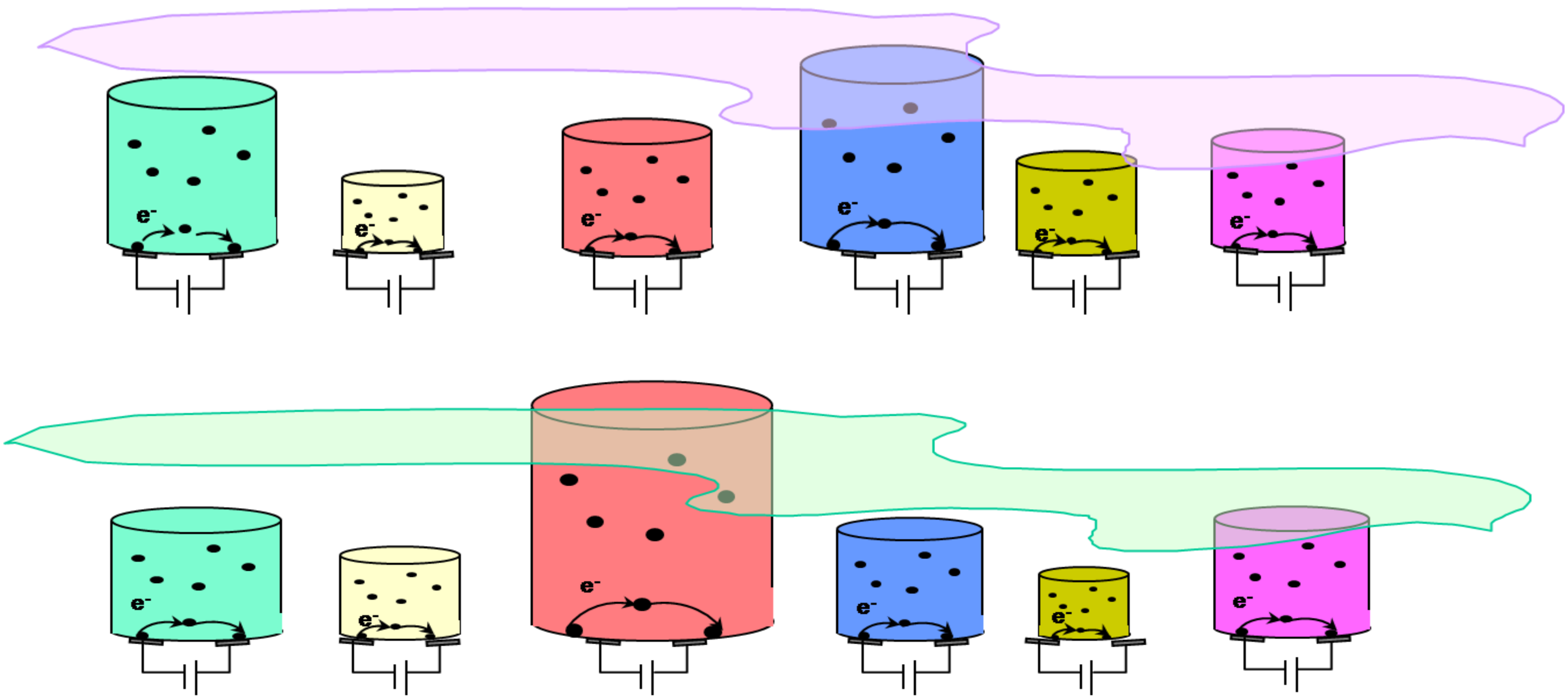
- This Enose uses different polymer films fabricated on top of electrodes.
- A baseline resistance of the electrodes is established in a controlled environment.
- When no changes in gas composition, the baseline resistance remains unchanged.



Graphic courtesy of NASA.

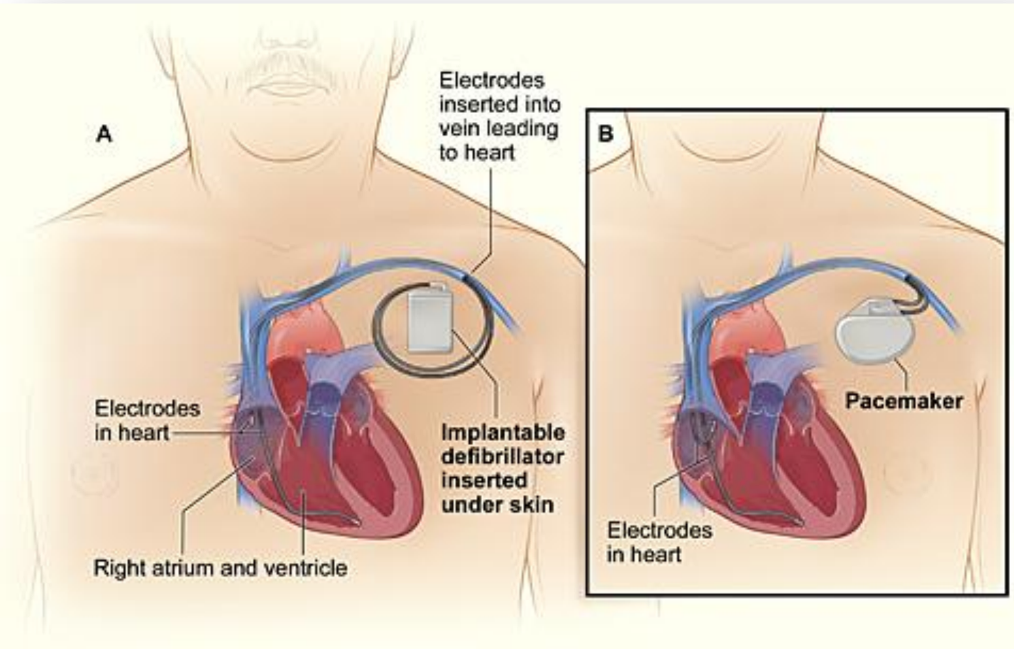
Electronic Nose (Enose)

When the initial gas composition changes, each polymer reacts differently, expanding or contracting. These changes in turn change the resistance of each electrode. These graphics illustrate two different gas compositions.



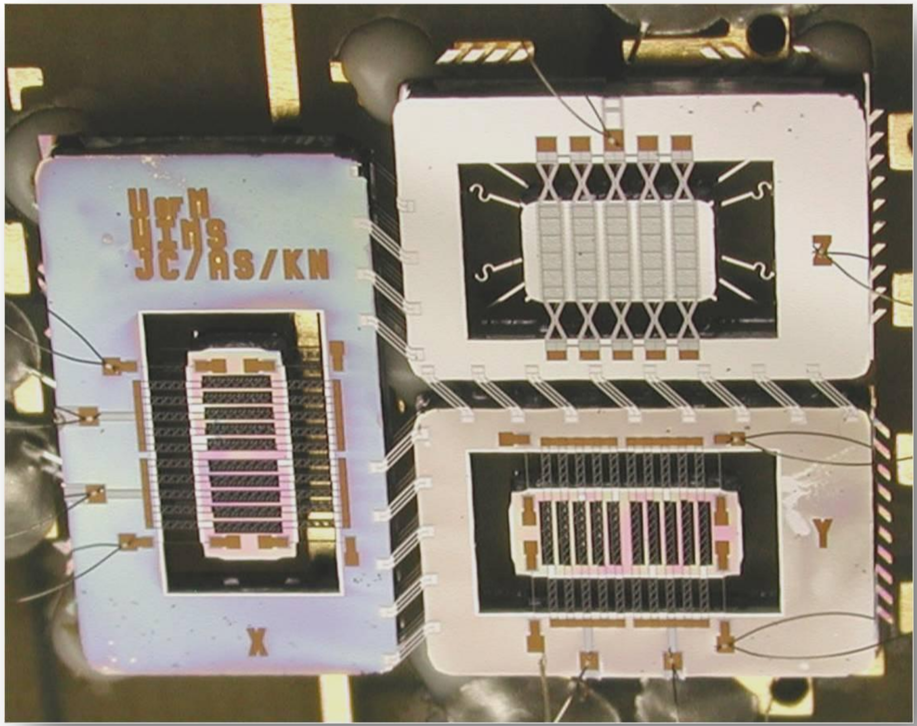
Graphic courtesy of NASA.

MEMS Accelerometers



- Pacemakers and defibrillators (internal and external)
- iPhones and Gaming devices
- Airbag deployment in cars
- Anticrash and anti-roll sensor
- Computer stabilization
- Camera stabilization
- GPS devices
- Power management devices
- Vibration sensors for motors, fans, and compressors

MEMS Accelerometers



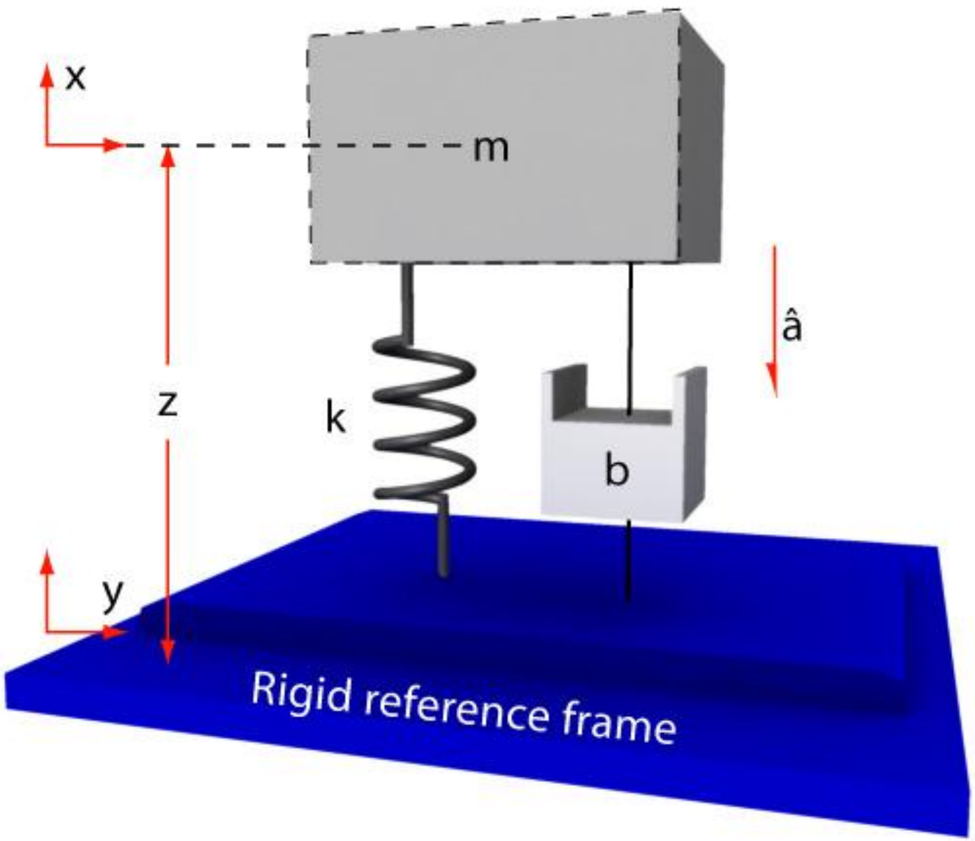
A MEMS accelerometer is used to detect linear motion in one direction.

Multiple accelerometers can be used to detect linear motion in several directions as well as tilt and vibration.

A 3-axes system of MEMS accelerometers:

- X and y axes use lateral in-plane accelerometers
- Z axis uses out-of-plane accelerometer

Basic Operation of Accelerometers



b = damping factor

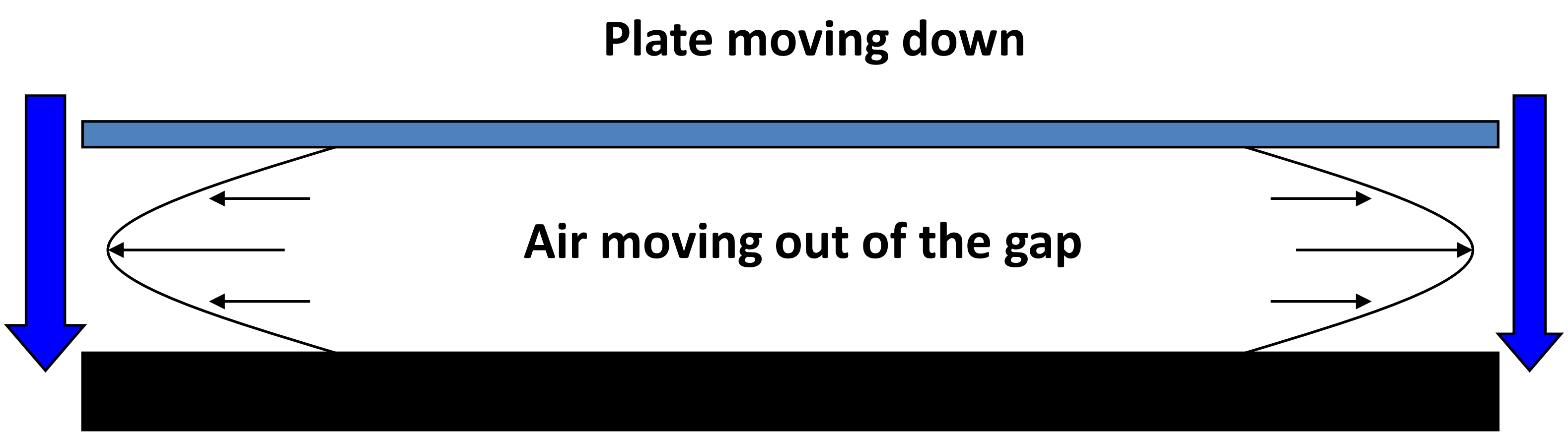
Accelerometers consist of a proof mass (m), spring(s), and anchor points.

- When the object on which the accelerometer is mounted moves or vibrates, the proof mass detects and “copies” the movement.
- The springs allow the movement of the proof mass.
- The distance that the proof mass moves is a factor of the acceleration (a), the size of the proof mass (m), and the spring constant (k) of the springs.

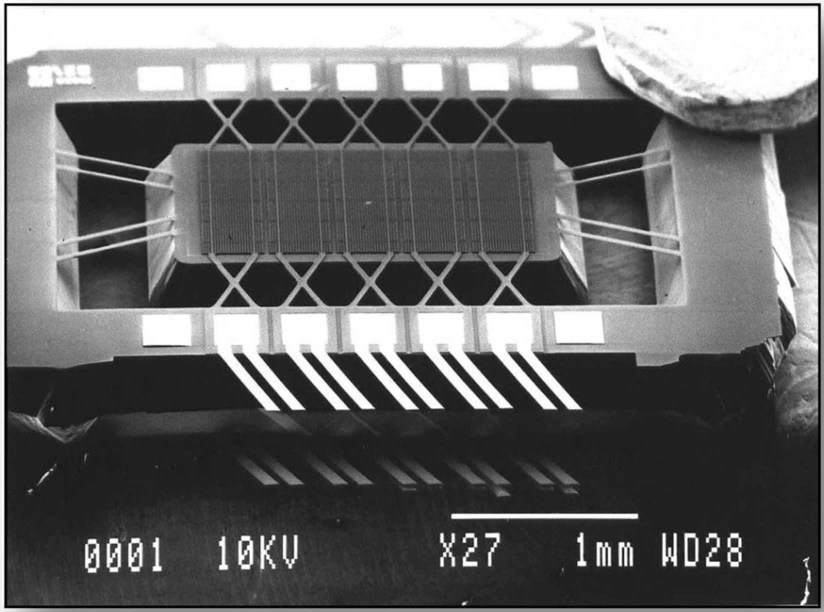
$$z = \frac{m}{k}\,a$$

Basic Operation of Accelerometers - Damping

- Damping is the capacity built into a mechanical system to correctly compensate for movement / oscillation.
- MEMS accelerometers have to react very quickly to motion and return just as quickly for the next motion that may occur; therefore, damping can be an issue.



Out-of-Plane MEMS Accelerometer

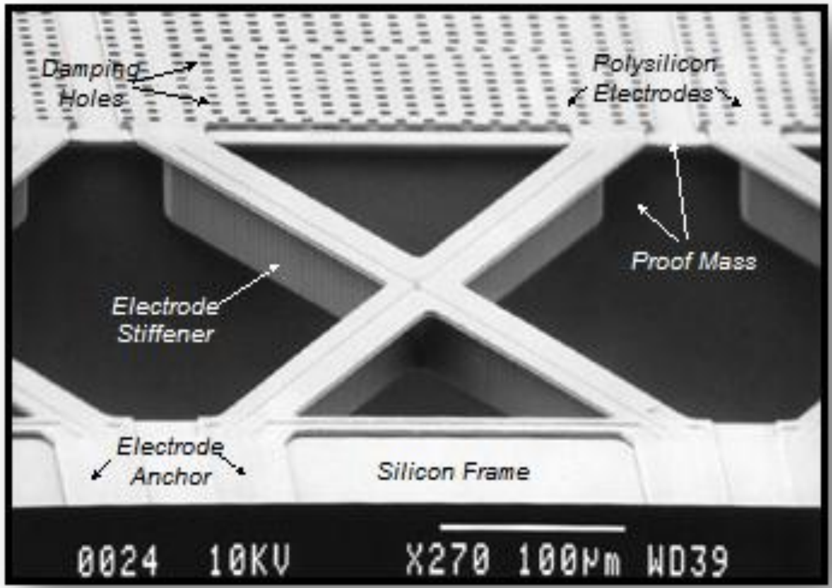


This accelerometer consists of a polycrystalline silicon (poly) inertial mass, or “proof mass”, suspended by fabricated springs.

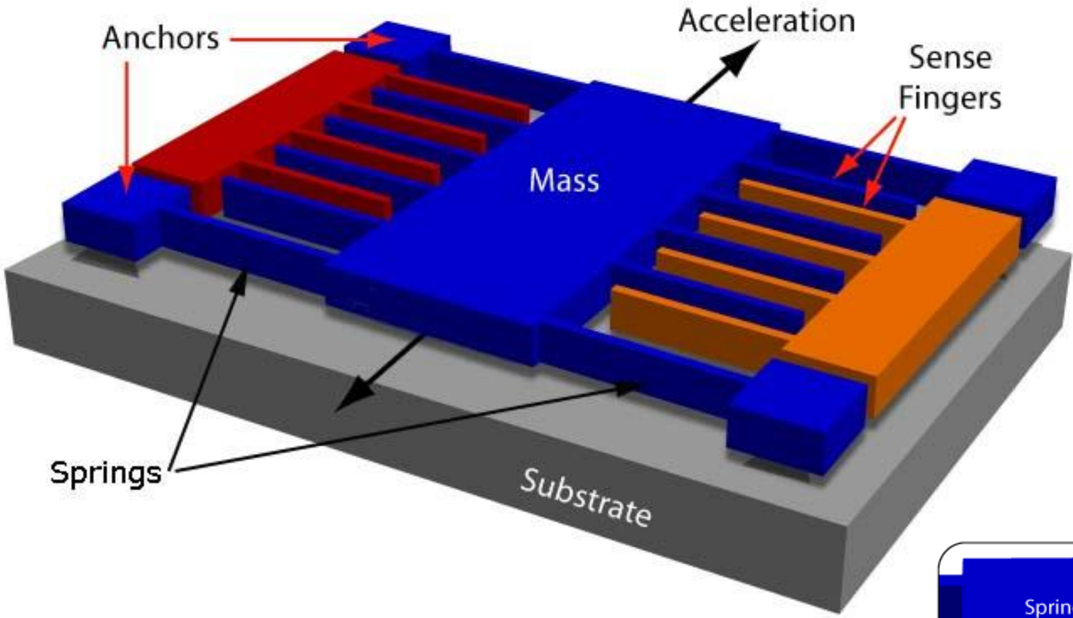
The springs are attached to an opening within the poly layer.

Damping holes are fabricated on the surface of the proof mass.

A sacrificial layer underneath the proof mass is used to allow the proof mass to move up and down.

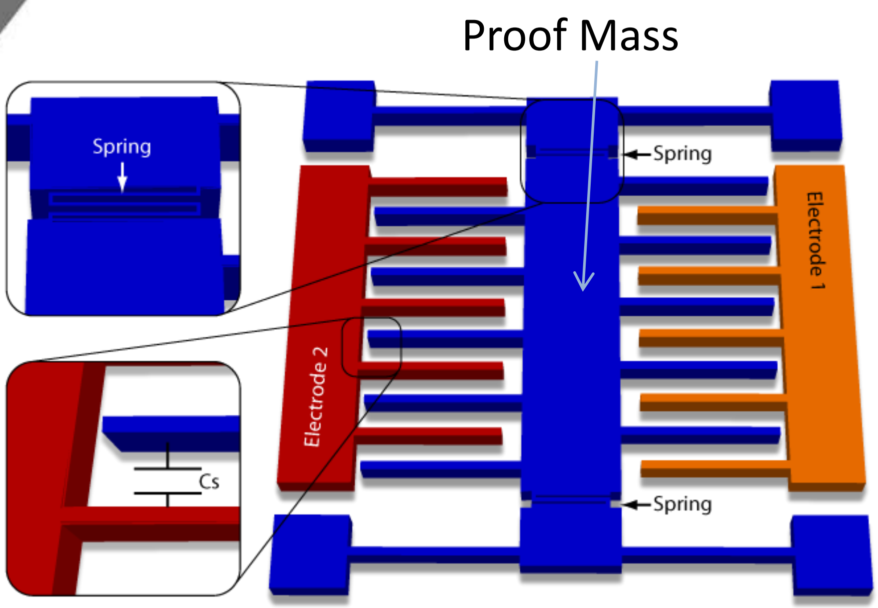


In-Plane MEMS Accelerometers



In-plane accelerometers use a set of fixed electrodes and moveable electrodes.

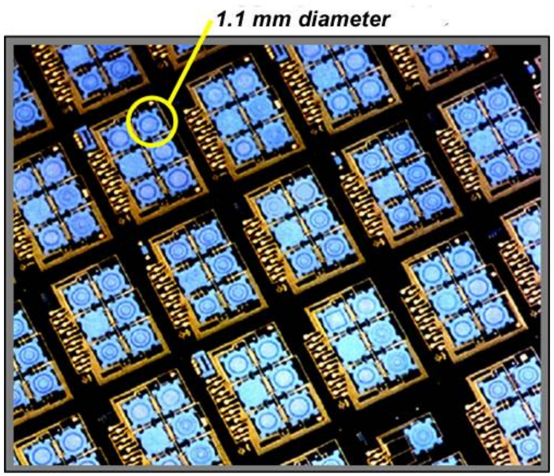
The moveable electrodes are part of a "proof mass" that moves linearly with acceleration or de-acceleration.



Pressure Sensors

- Automotive
  - Absolute air pressure
  - Tire Pressure
  - Fuel Pressure
  - Air Flow
- BioMedical
  - Blood Pressure Sensors
  - Intracranial Pressure
  - Cerebrospinal fluid Pressure
  - Intraocular Pressure
  - Endoscopes for organ pressure
- Other
  - Barometric Pressure
  - Smart Dust

MEMS Blood Pressure Sensors
Photo courtesy of Lucas NovaSensor, Fremont, CA]



Barometric Pressure Sensors (Photo courtesy of Khalil Najafi, University of Michigan)

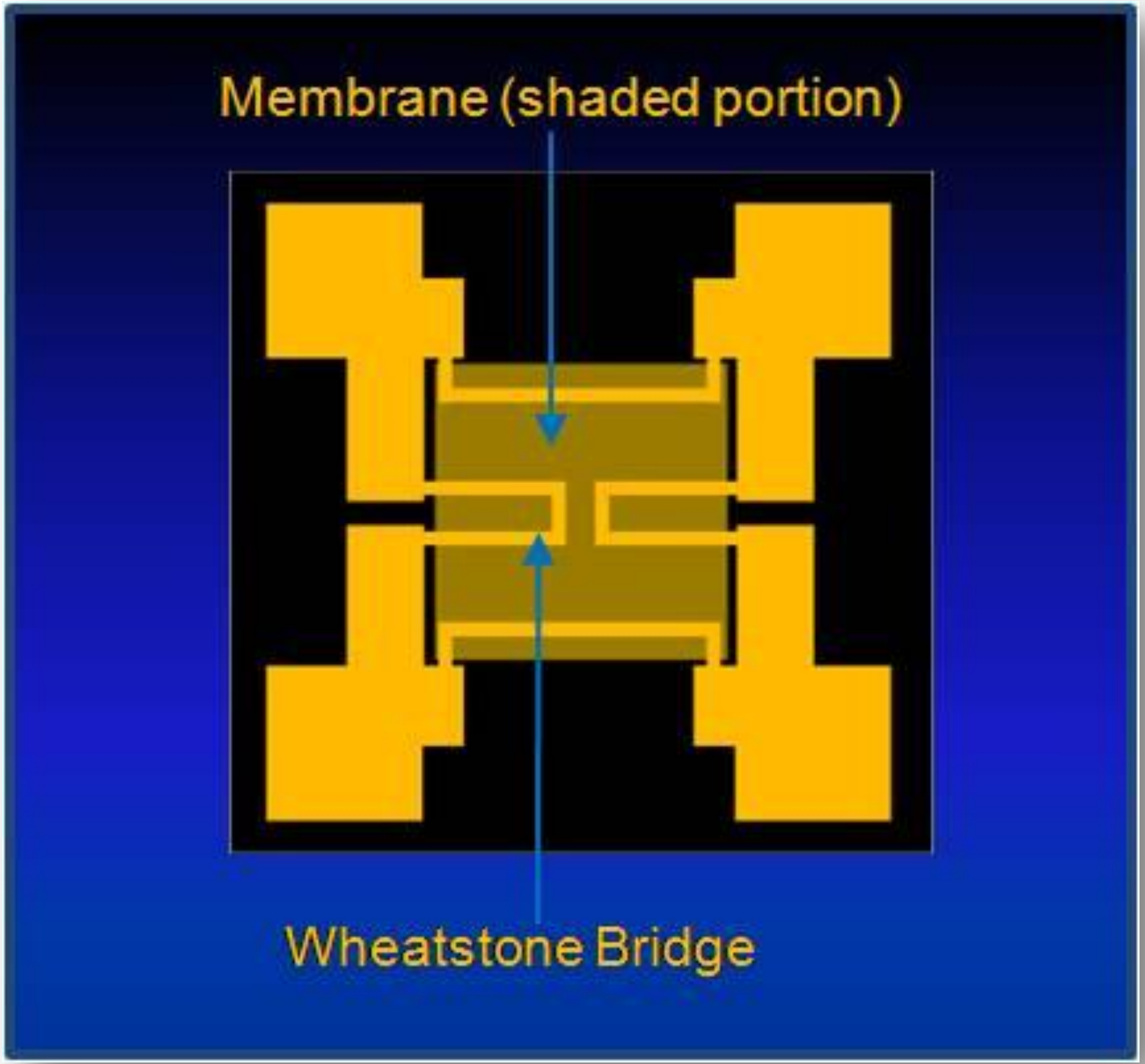
Pressure Sensors

Components:

Membrane

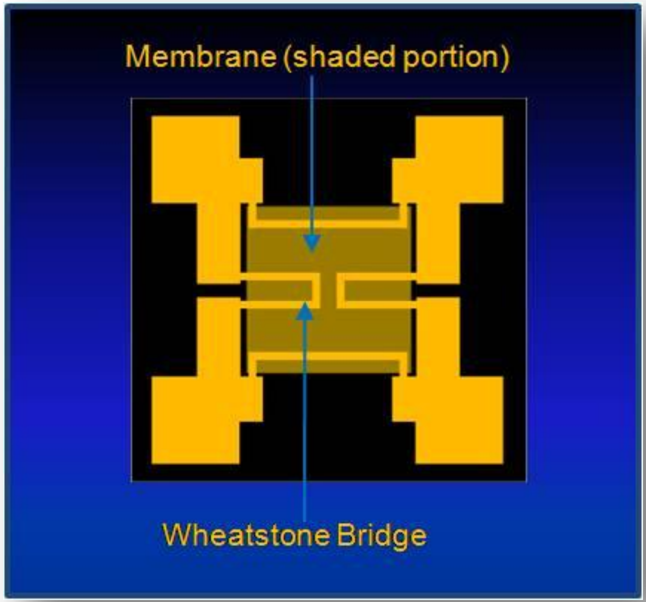
Sensing Circuit

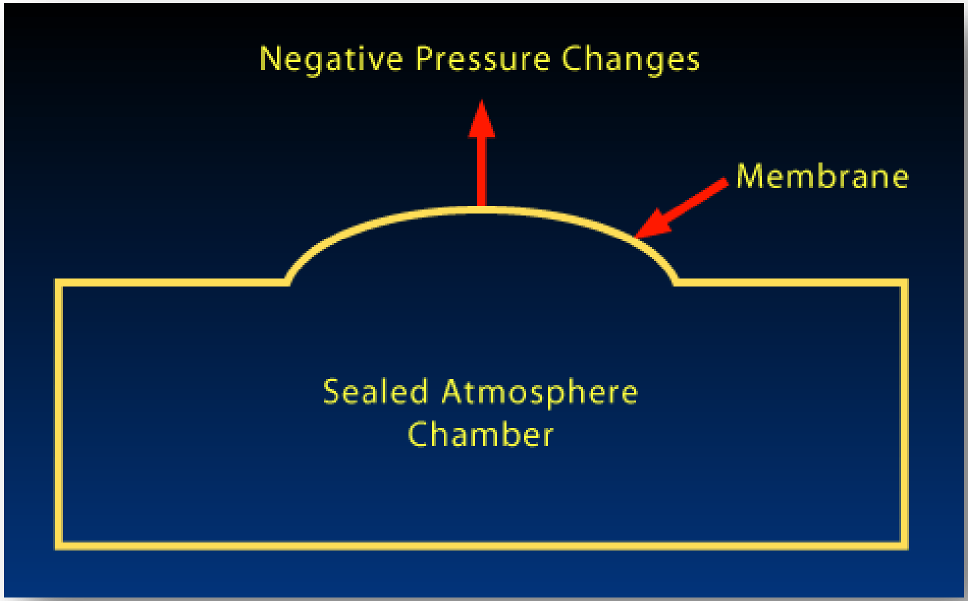
Sealed Chamber



Pressure Sensors

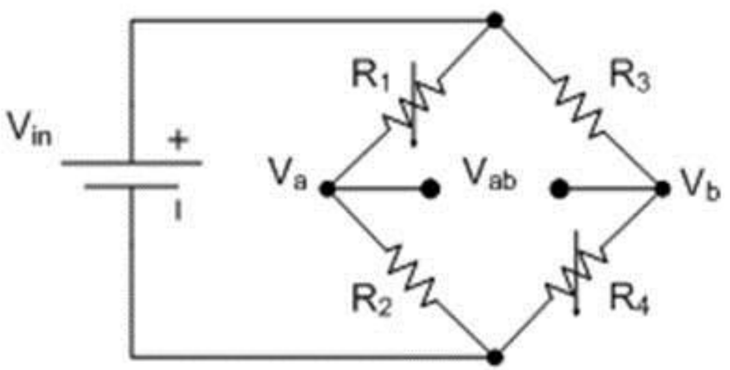
Membrane

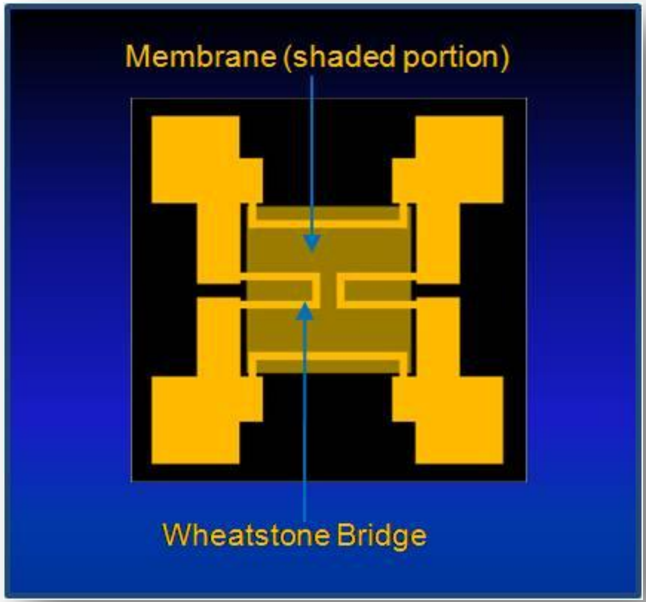


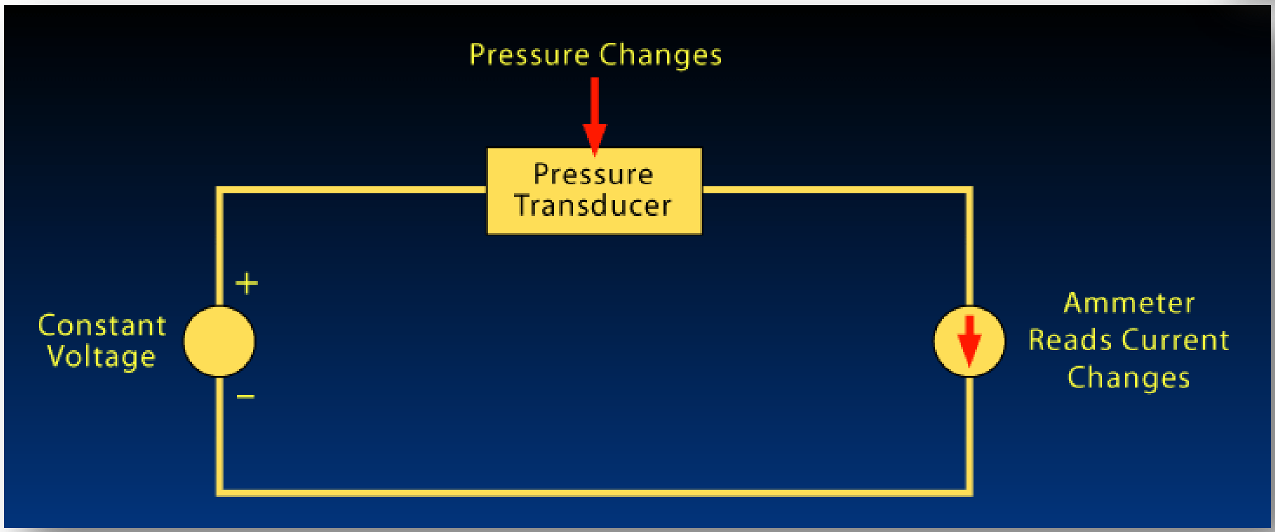


Pressure Sensors

Sensing Circuit



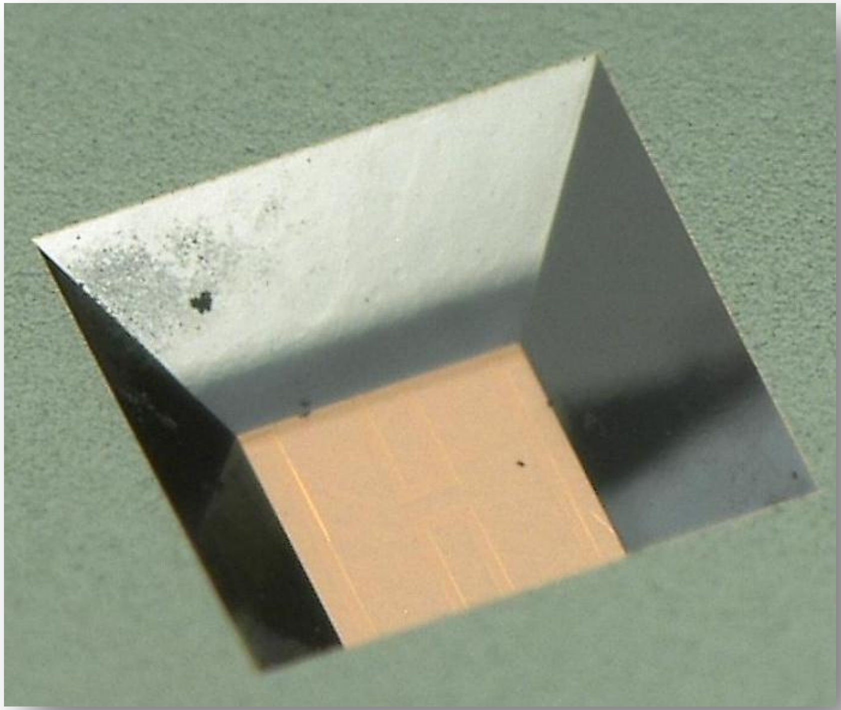


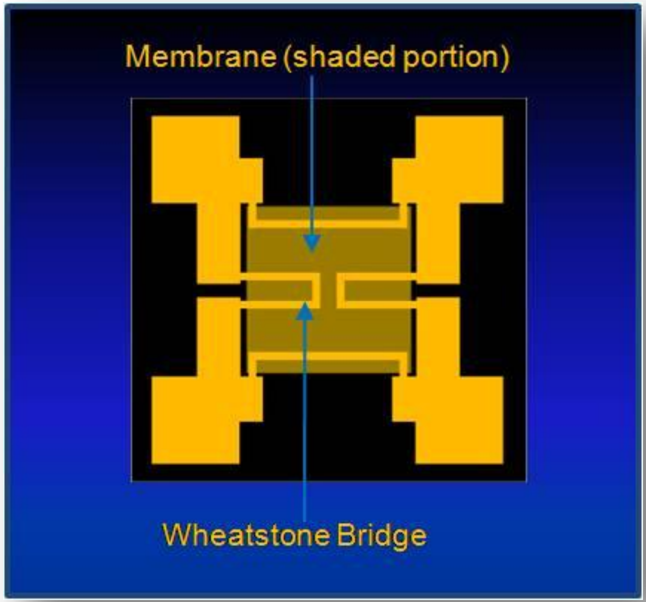


$$R = \rho \frac{L}{Wt}$$

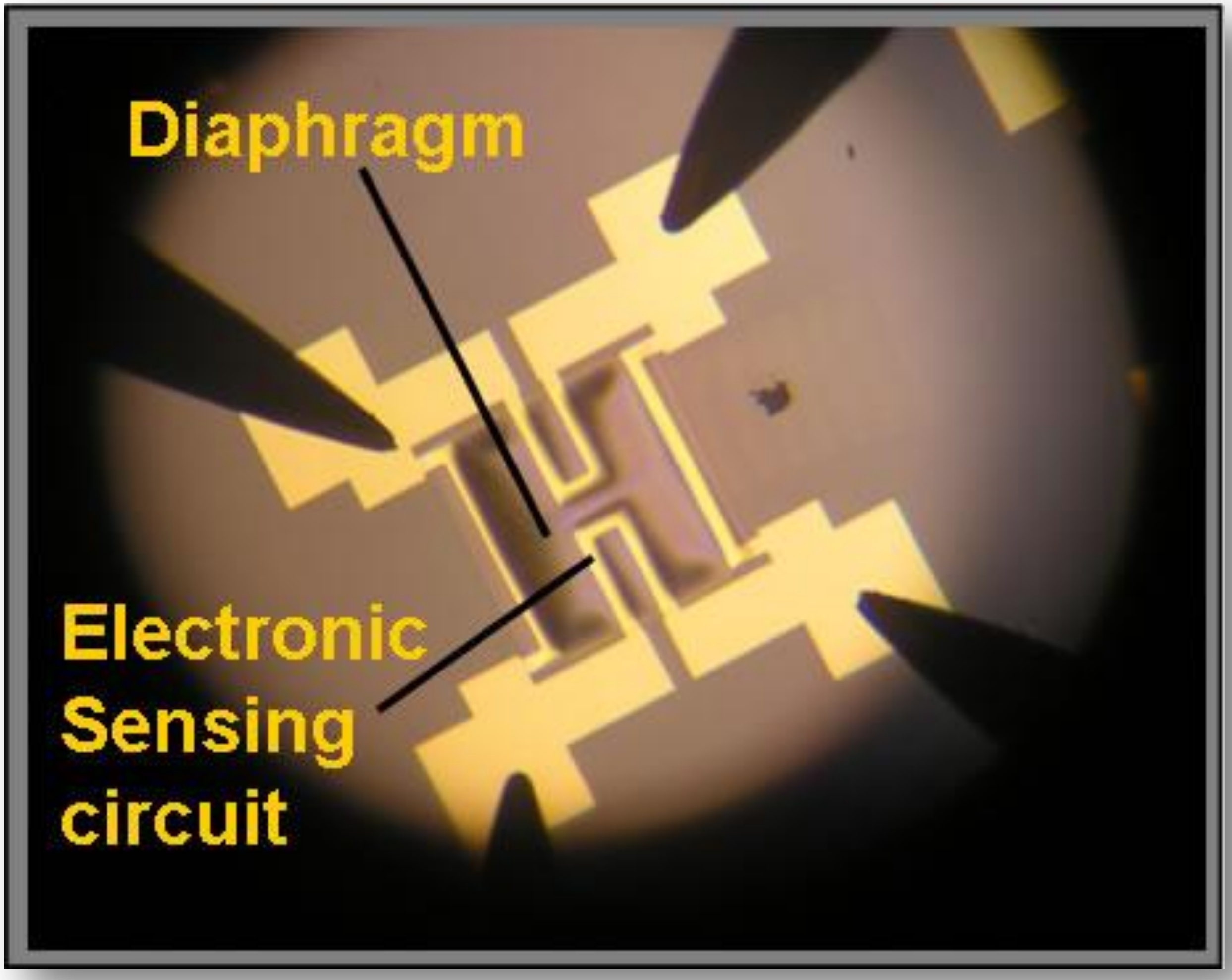
Pressure Sensors

Chamber

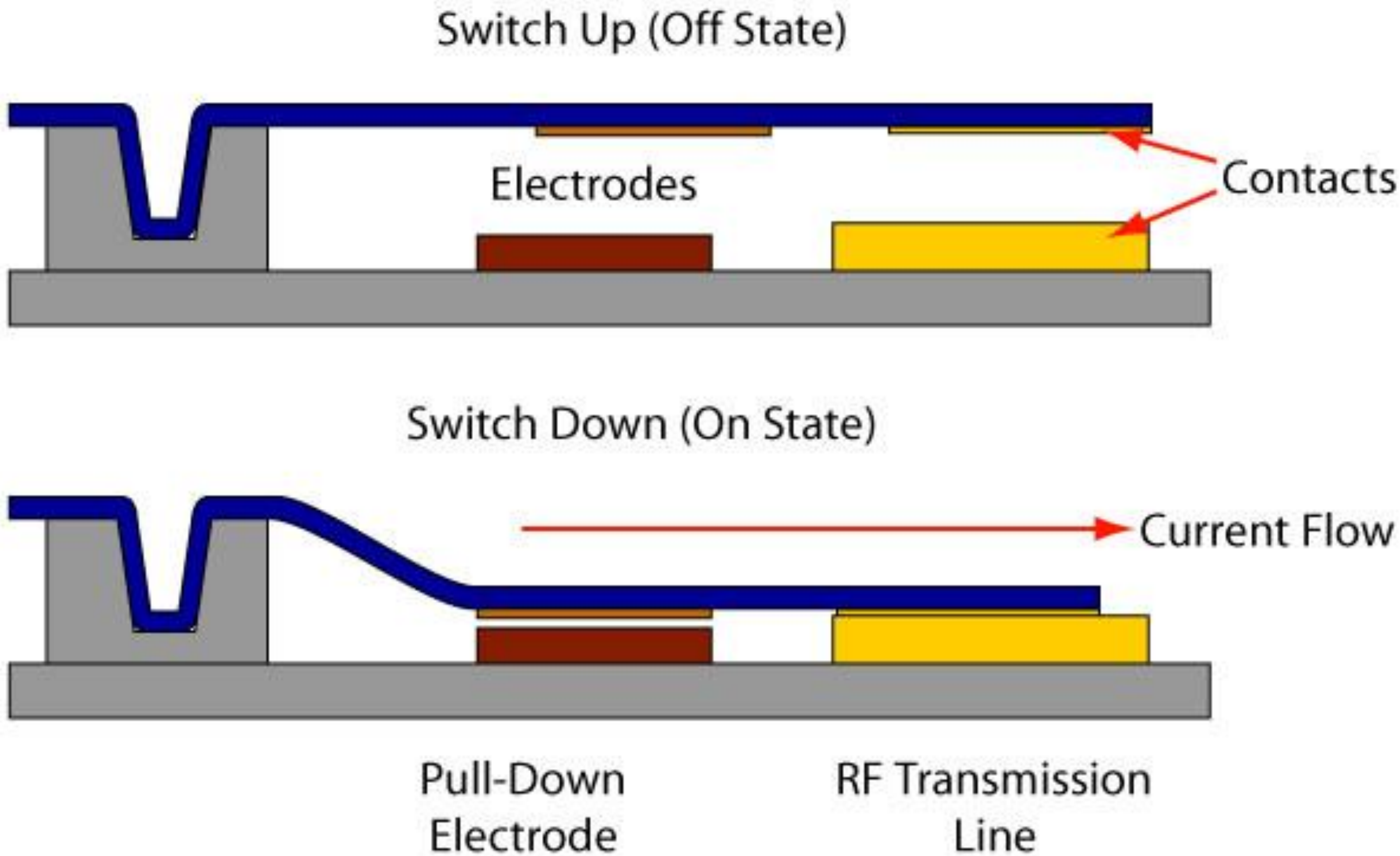




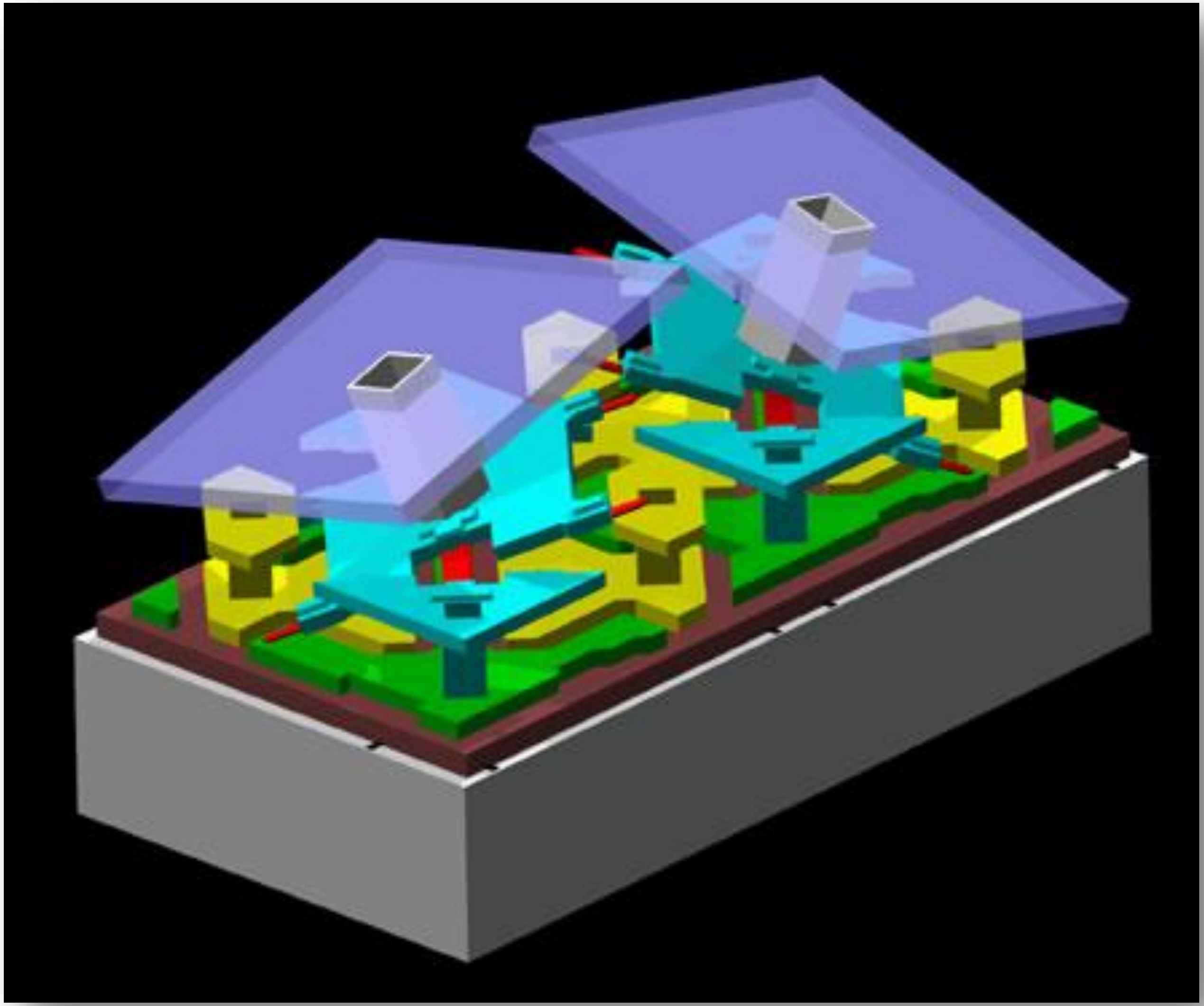
Pressure Sensors



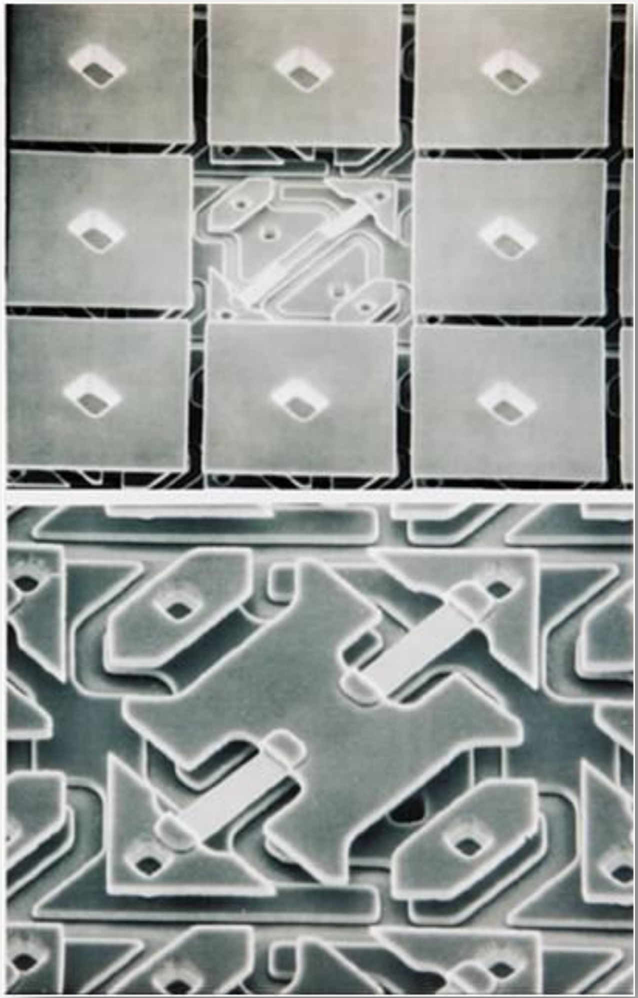
MicroActuators - Switches

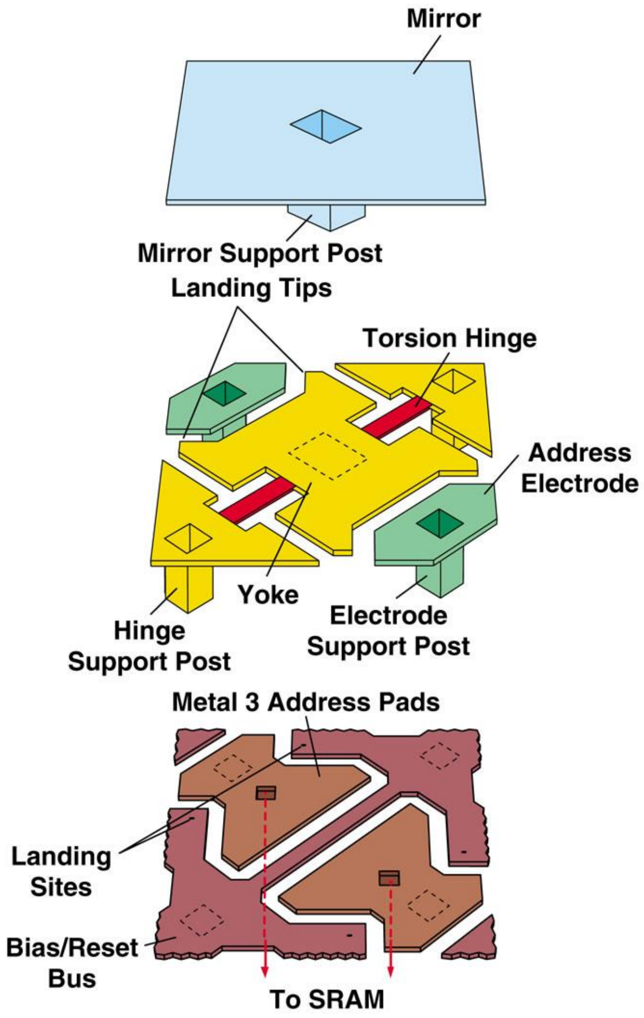


Digital Mirror Devices



Digital Mirror Devices





All DMD images and DLP images courtesy of Texas Instruments

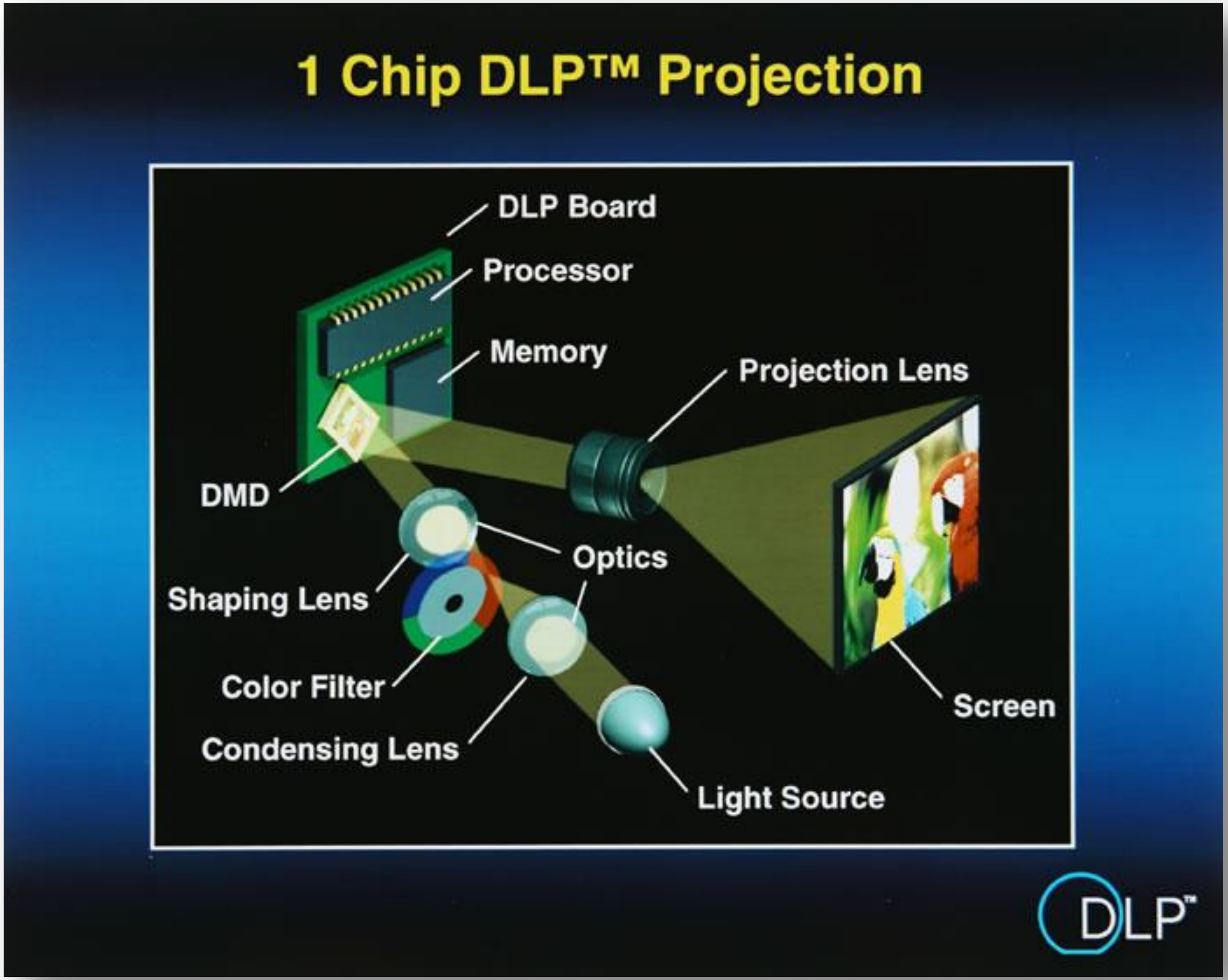
Poll Question

How fast can these mirrors tilt back and forth?

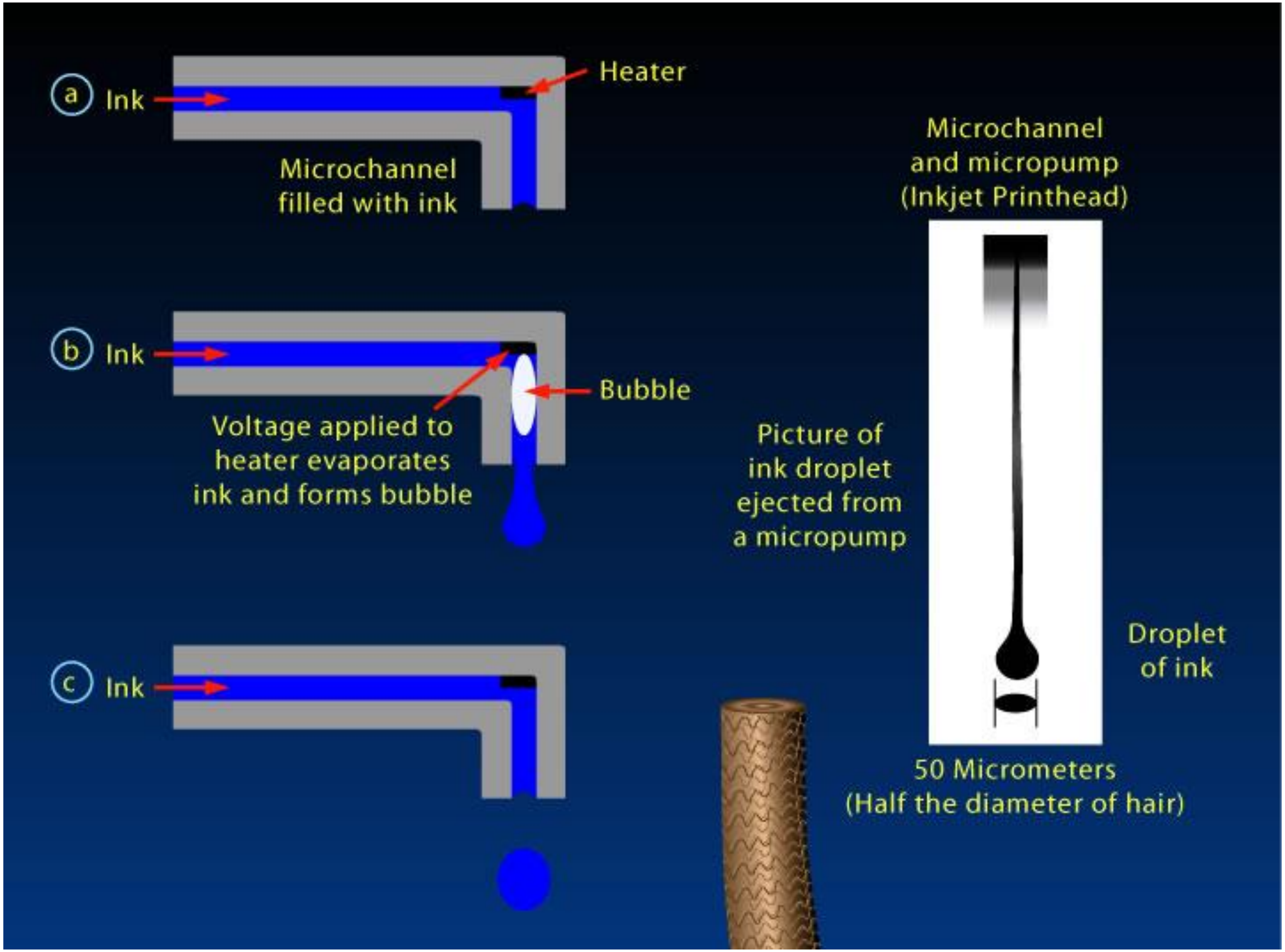
A. 15,000 times per minute
B. 30,000 times per minute
C. 15,000 times per second
D. 30,000 times per second

Answer: D

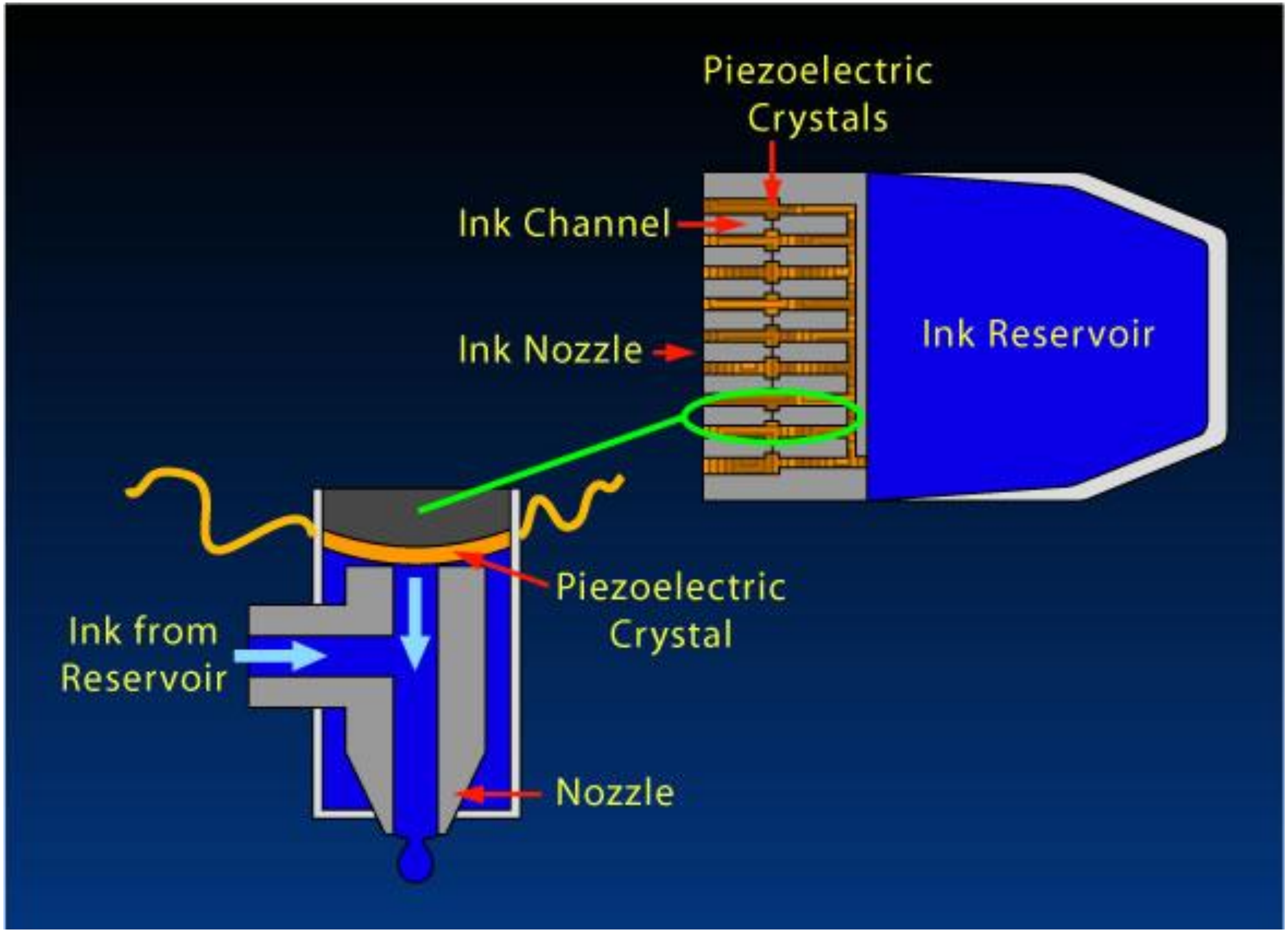
Digital Light Projection (DLP)



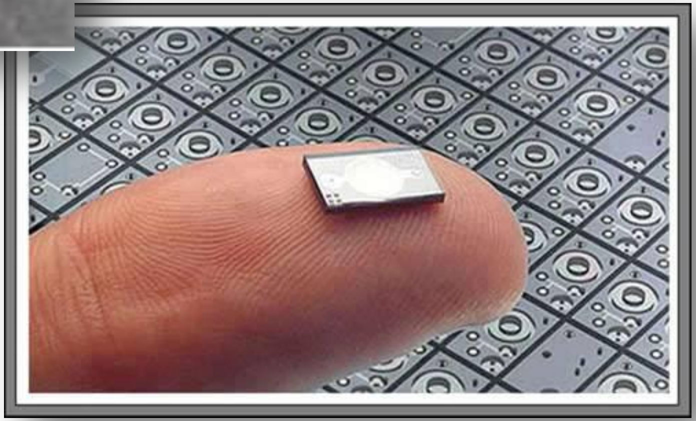
Bubble Jet Printers



Piezoelectric Ink Jet Printers

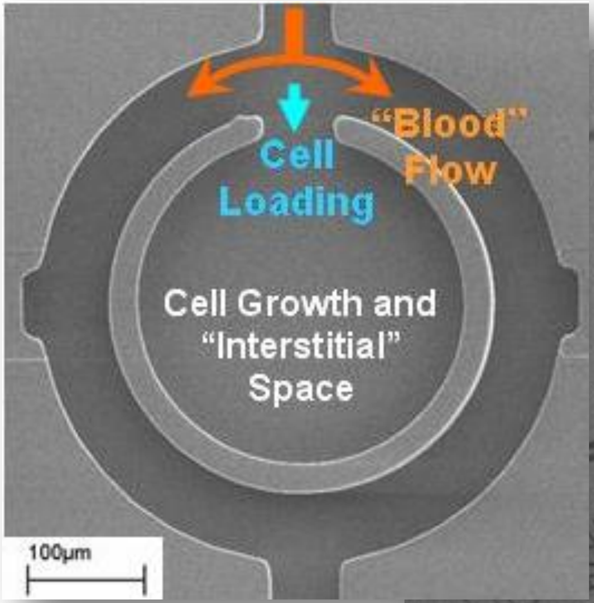


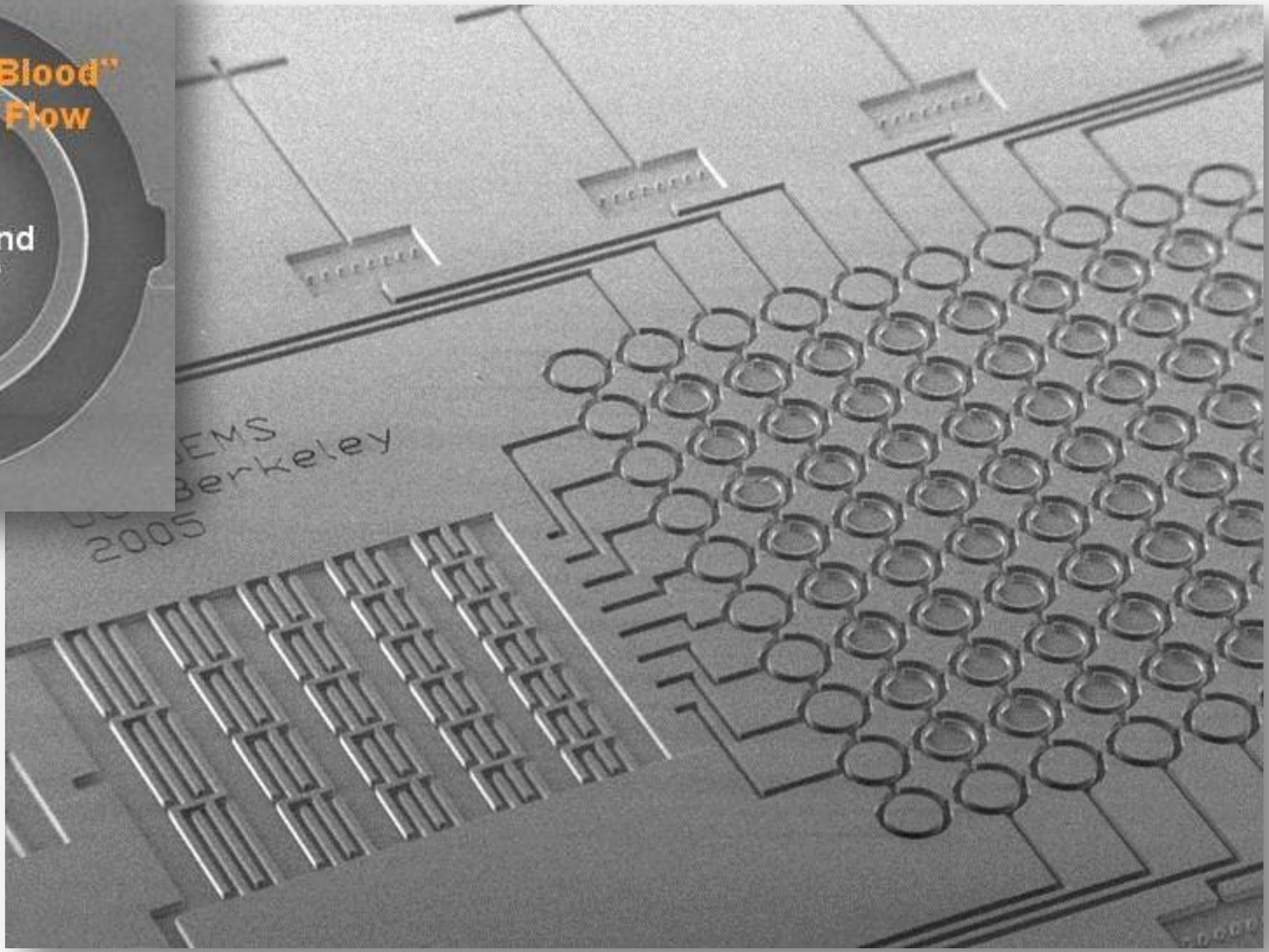
More Micro-Pumps



Printed with permission from Debiotech SA

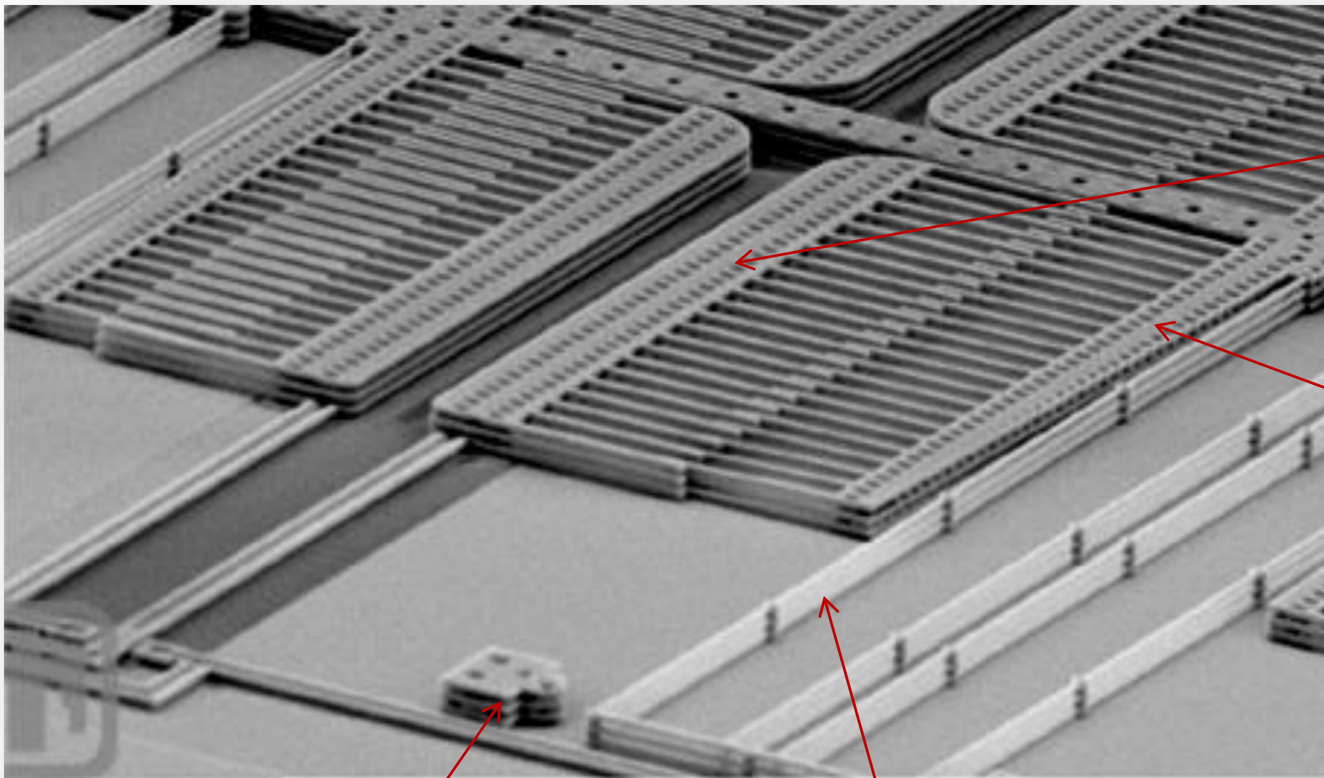
Micro-fluidics



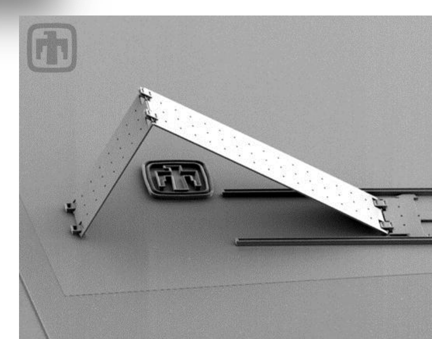


Developed by and images courtesy of BioPOETS Lab, UC-Berkeley

Electrostatic Comb Drive Actuators

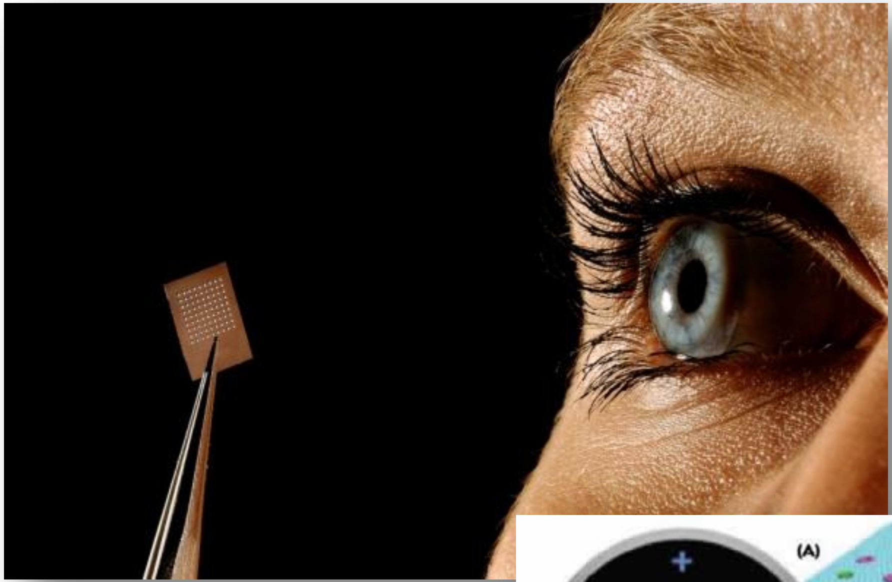


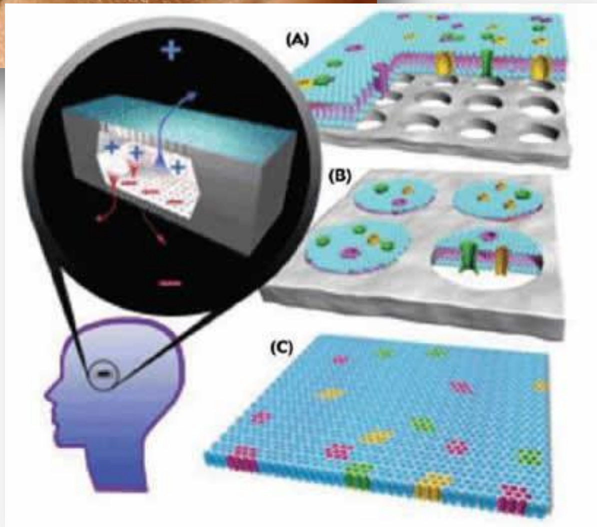
Comb drive showing Travel Stops and Springs of a Comb drive
[Images courtesy of Sandia National Laboratories, www.mems.sandia.gov]



Other MEMS Devices

- MEMS Optical Network Switches
- Micro-batteries
- And of course many Biomedical devices!



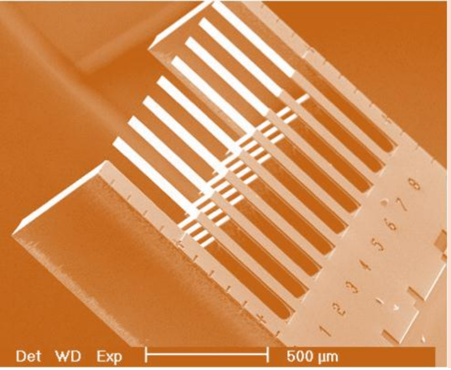


Images courtesy of Sandia National Laboratories

Where Can You Find Out More?

SCME Learning Modules available at: **www.scme-nm.org**

- Introduction to Transducers, Sensors, and Actuators
- MEMS Applications
- MEMS Cantilevers
- History of MEMS
- MTTC Pressure Sensor Process
- Wheatstone Bridge



Thank You For Joining Us

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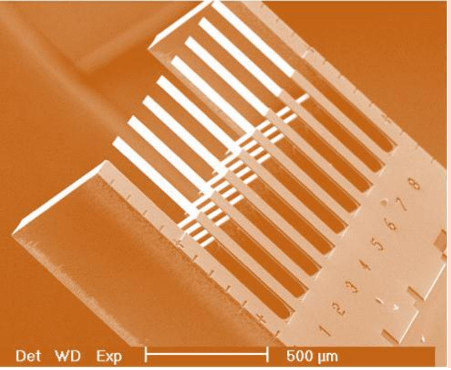
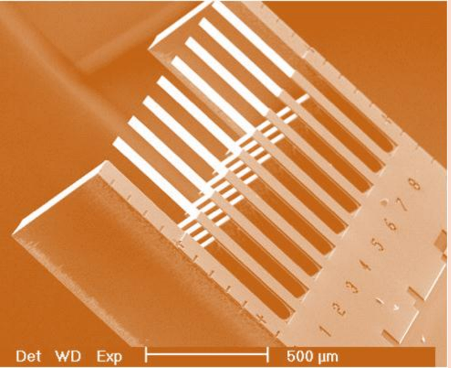


How Can We Serve You Better?

Please take 1 minute to provide your feedback and suggestions

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

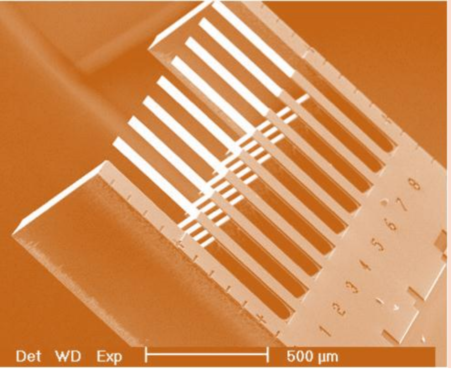


Webinar Resources

SCME Southwest Center for Microsystems Education

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

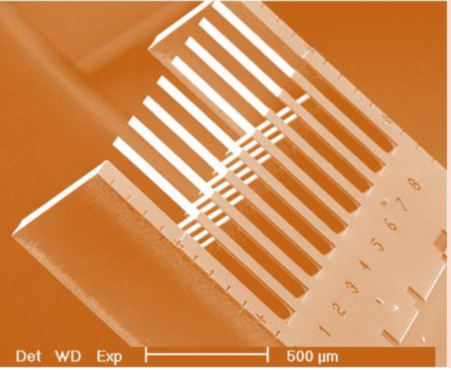
www.scme-nm.org



SCME Upcoming Webinars

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 102

How do Microsystems Work?