

ME490B Case study 1: Bio-medical sensors

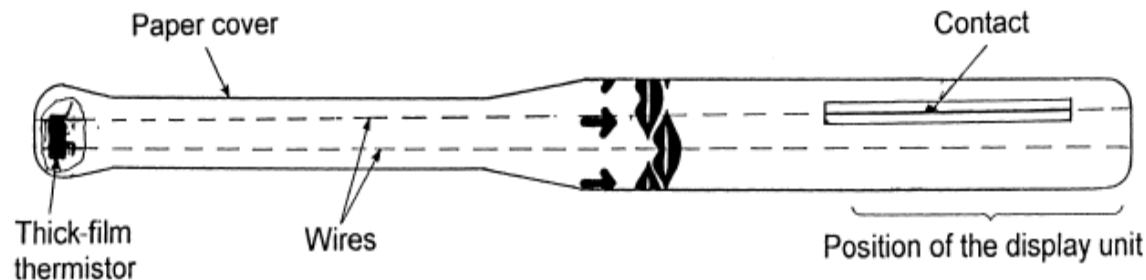
Fall 2014

Store No : 404820



Electronic thermometers

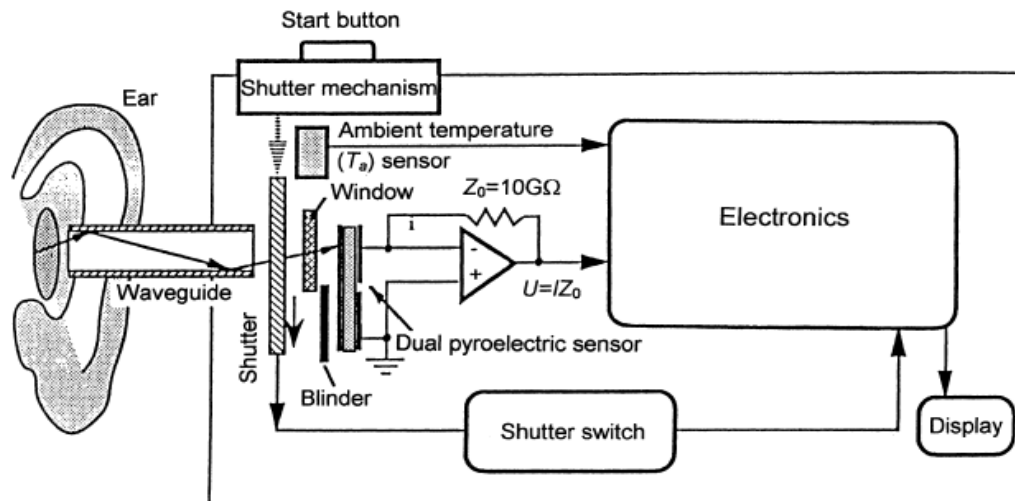
They generally contain diodes as temperature-sensing elements with a special package design that can assure small thermal capacity and good thermal conductivity to the environment. They have relatively short response times and good visible display units



Structure of a disposable oral thermometer.



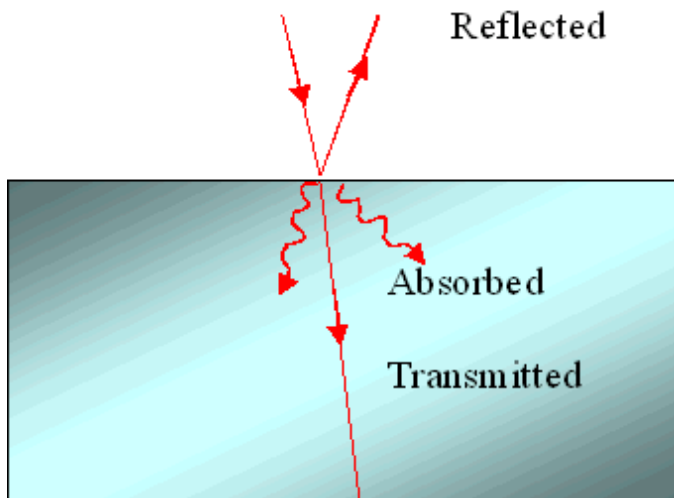
Radiation Ear Thermometer



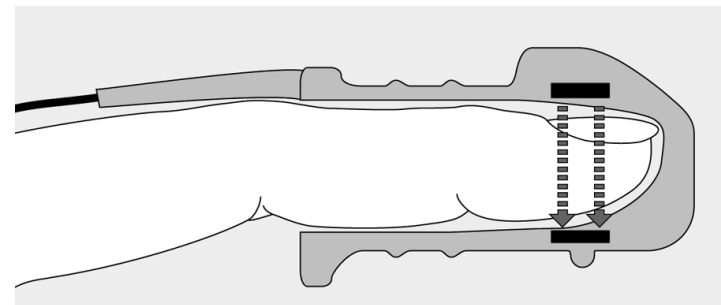
Pulse Oximetry

Absorption of Light

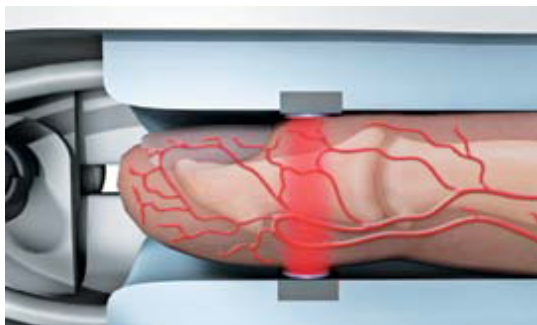
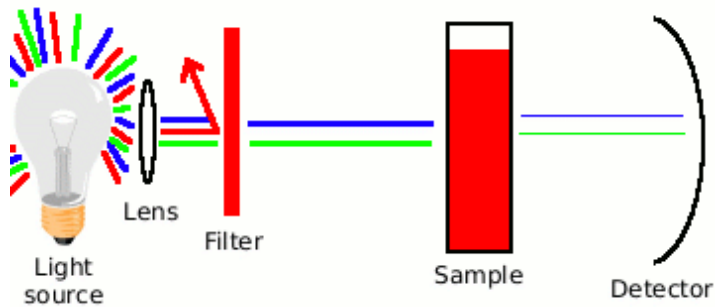
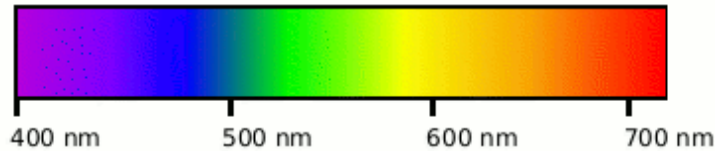
- Absorption depends on the electromagnetic frequency of the light being transmitted (i.e. the color) and the nature of the atoms of the object.



Commercial pulse oximeter



Wavelength and absorption

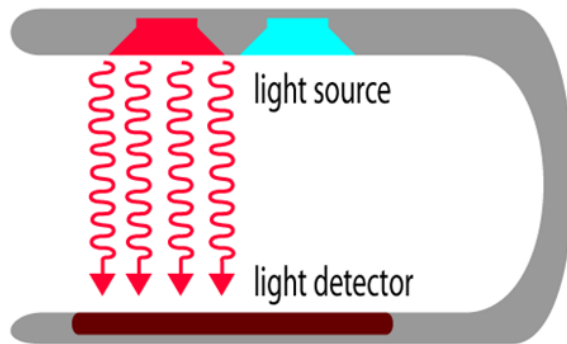


Light path in a colorimeter

- When the filtered light hits the sample, some of the light is absorbed. Darker samples will absorb more of the light while paler samples will absorb less of the light. The detector measures the amount of light which is transmitted through the sample.

Pulse oximeter mechanism

- Within the SpO₂ sensor, light emitting diodes shine red and infrared light through the tissue.
- Most sensors work on extremities such as a finger, toe or ear. The sensor measures the amount of red and infrared light received by the detector and calculates amount absorbed.



- Hemoglobin light absorption graph

Figure 1

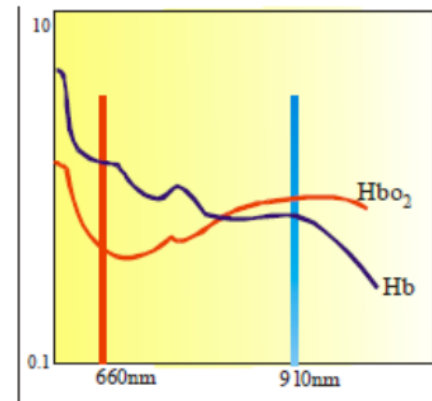


Figure 2

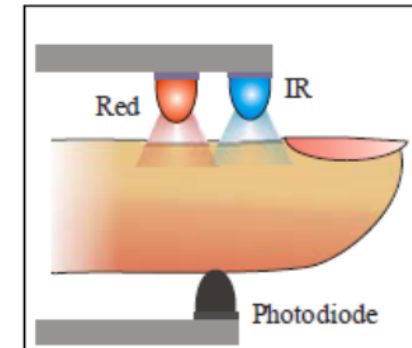


Figure 1. Absorption coefficient for two types

Figure 2. Basic idea of a pulse oximeter of haemoglobin at red and infrared wavelength.

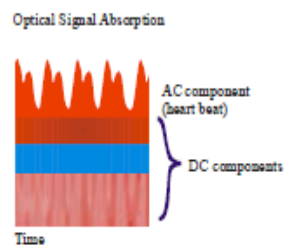
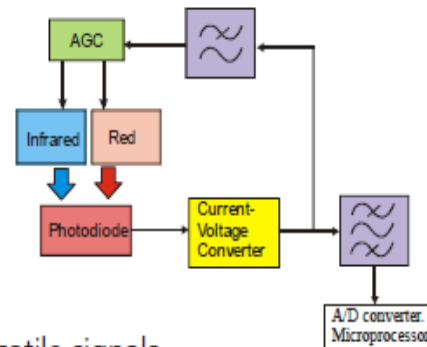


Figure 3. AC and DC pulsatile signals

Figure 4. System flow diagram



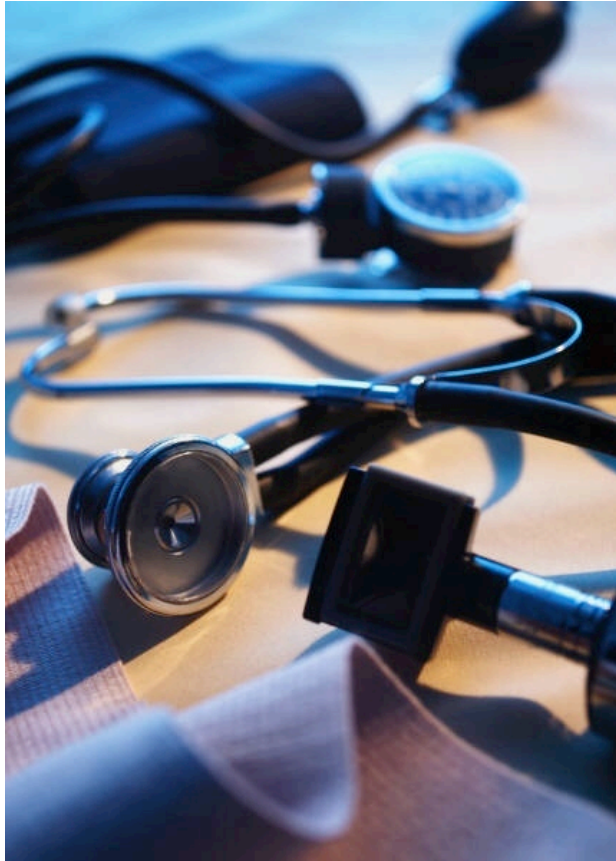
- Pulse oximeters measure the absorption of red and infrared light by pulsatile blood.

Types of products



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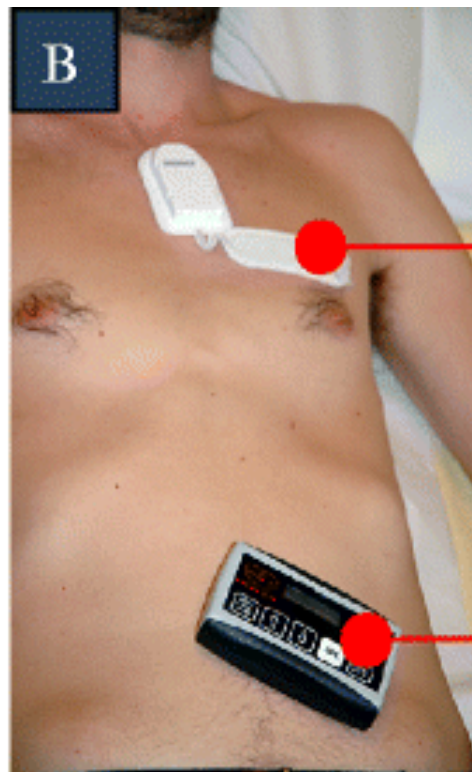
What are Wireless Biomedical Sensors?



A new technology that advances the way we gather data about our patients.

ECG Sensor

Image from Journal of Medical Systems

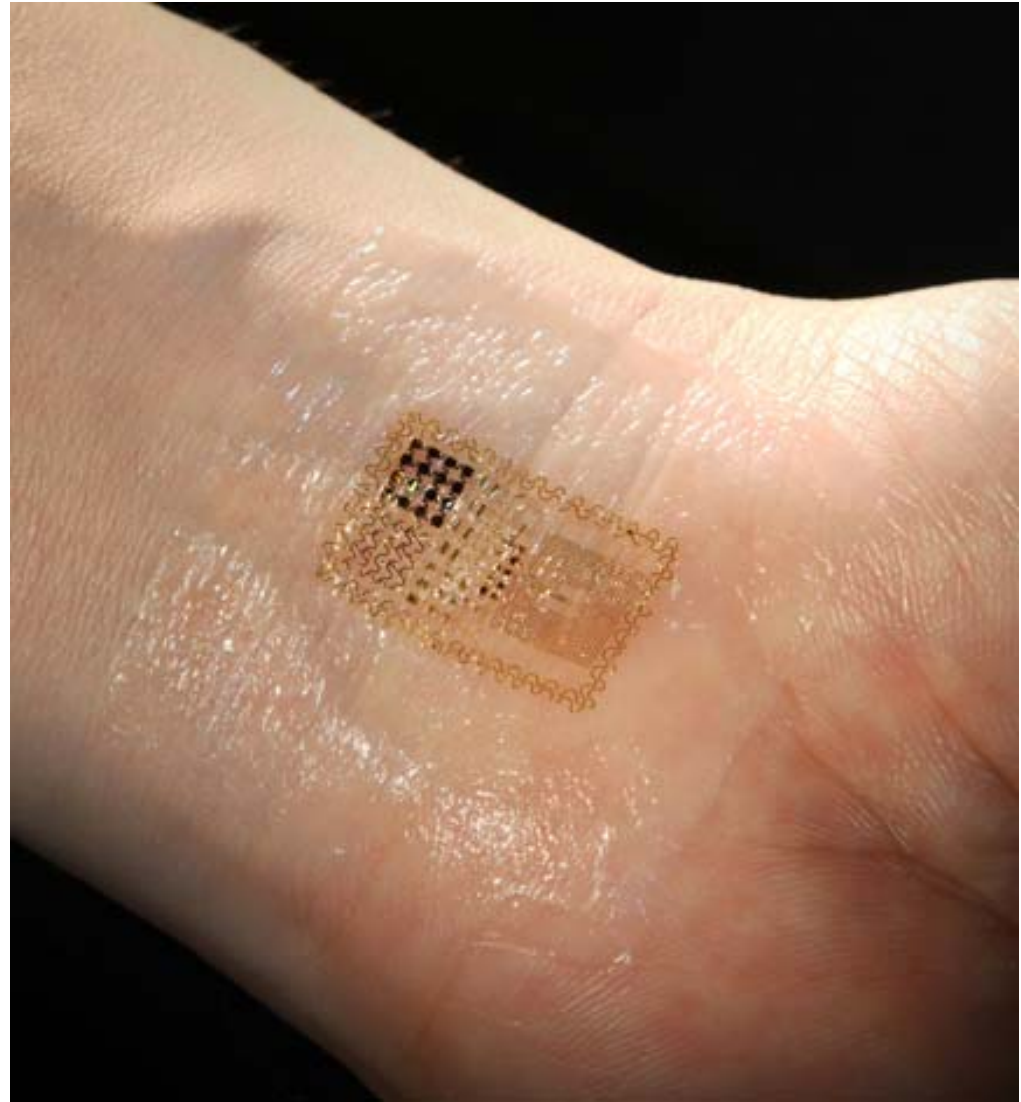


Wireless
ECG Sensor

Hand Held
Device (HHD)

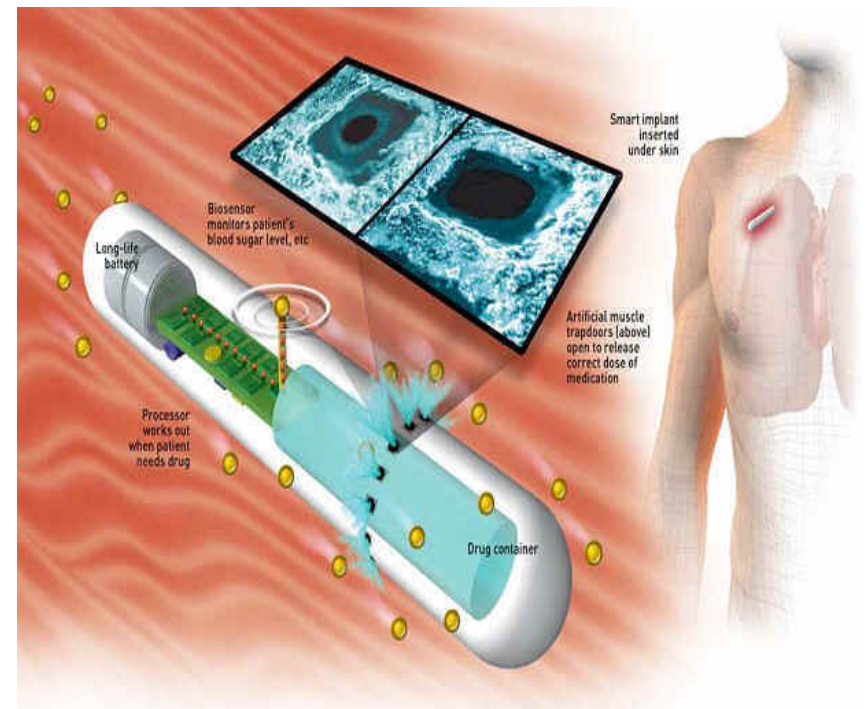
electrocardiogram EKG

Electronic
Medical
Sensors For
The Human
Body Stick
Like
Aesthetic
Tattoos



Smart Pill

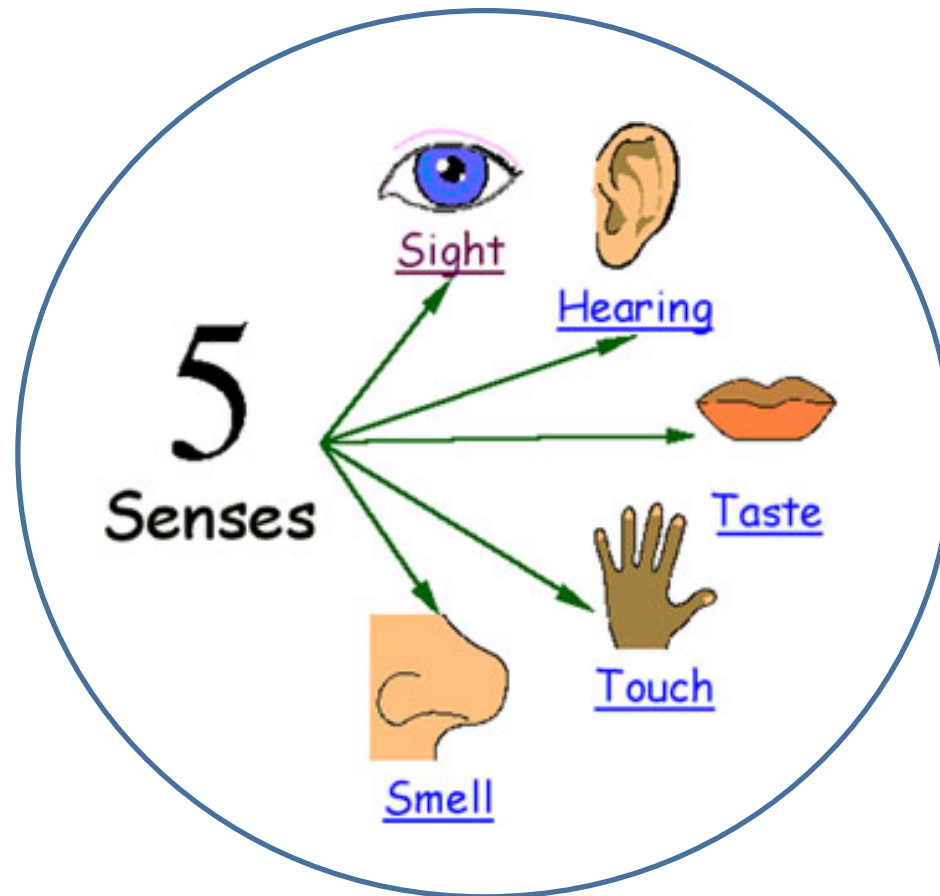
- A MEMS device that can be implanted in the human body.
- Consists of
 - biosensors
 - Battery
 - Control circuitry
 - Drug reservoirs
- The biosensors sense the substance to be measured, say insulin.
- Once this quantity falls below a certain amount required by the body, the pill releases the drug.



<http://mmadou.eng.uci.edu/>

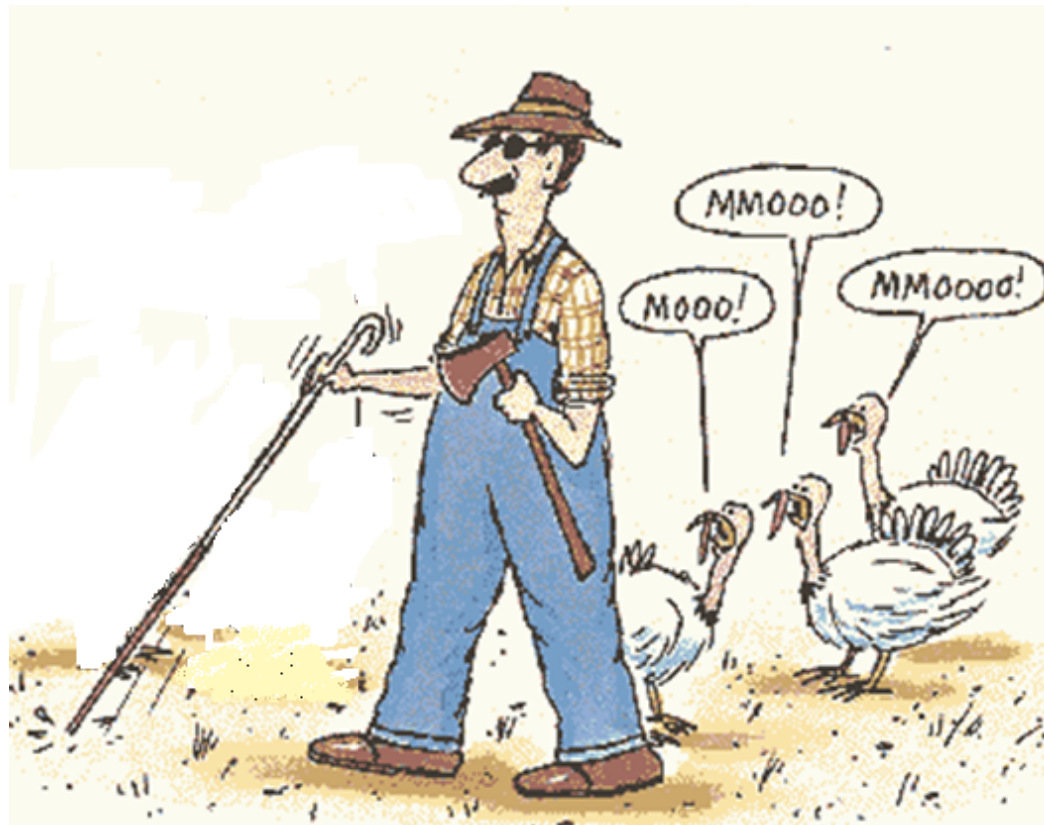
5 Senses

Sensing means becoming aware of...



What if I can see?

Add instrumentation...



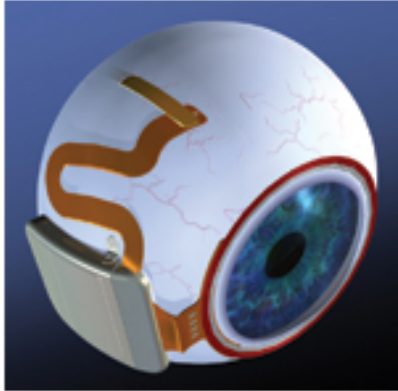


Figure 2 Researchers at the Boston Retinal Implant Project implanted an array in the subretinal area of a pig but affixed most of the prosthesis—a titanium, hermetically encased electronics assembly—to the outer surface of the sclera. A serpentine electrode array extends from the case to the superior temporal quadrant of the eye (courtesy Veterans Administration Boston Healthcare System and the Boston Retinal Implant Project).

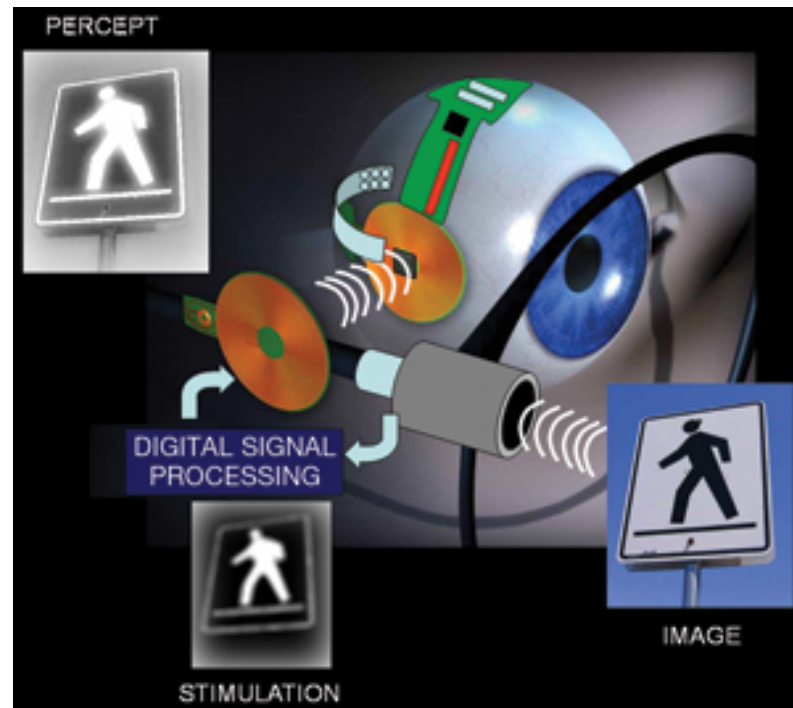


Figure 3 This system has an external video-capture unit and a transmitter that wirelessly sends image data to the implanted portion of the device (courtesy Veterans Administration Boston Healthcare System and the Boston Retinal Implant Project).



www.shutterstock.com · 128655251



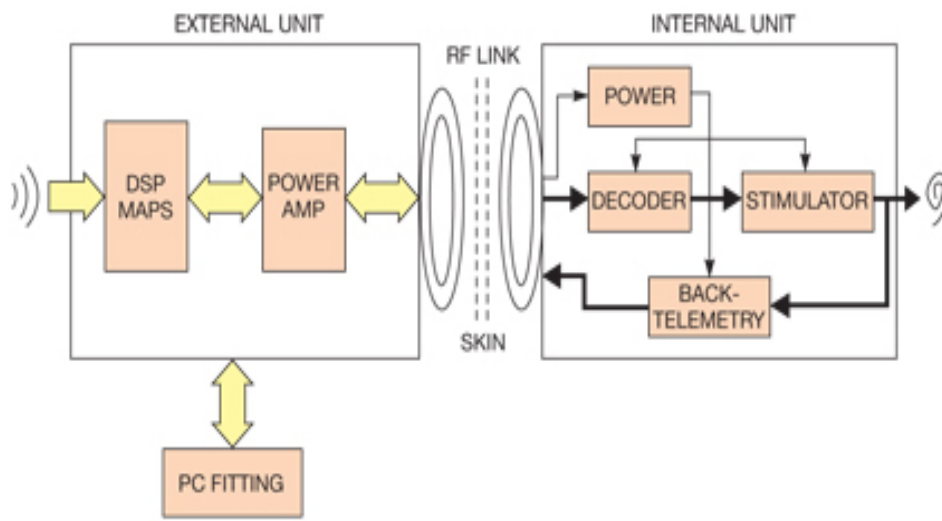


Figure 6 A feedback system monitors critical electrical and neural activities in the implants and transmits these activities back to the external unit (courtesy IEEE).

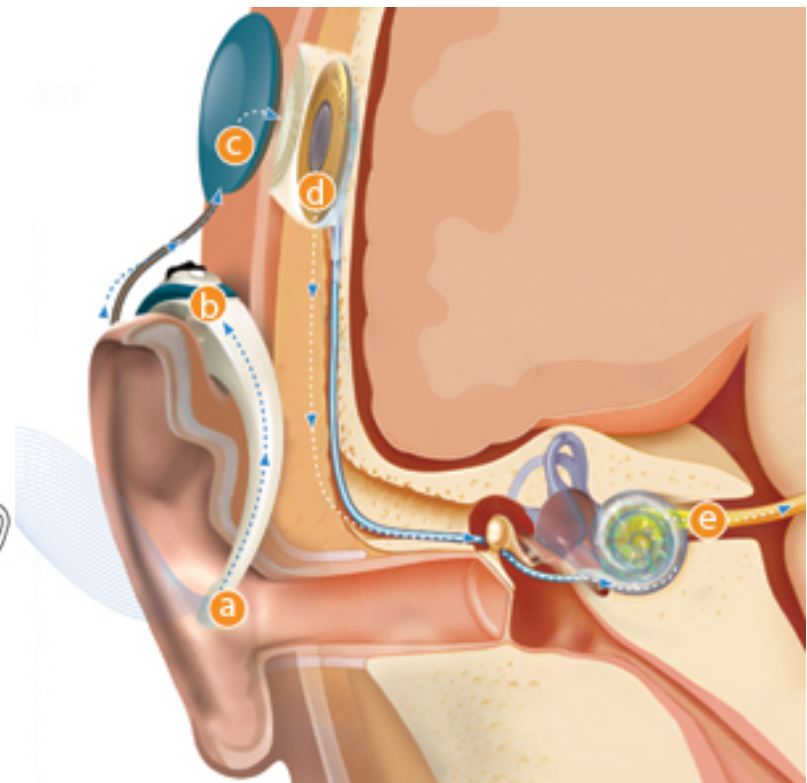
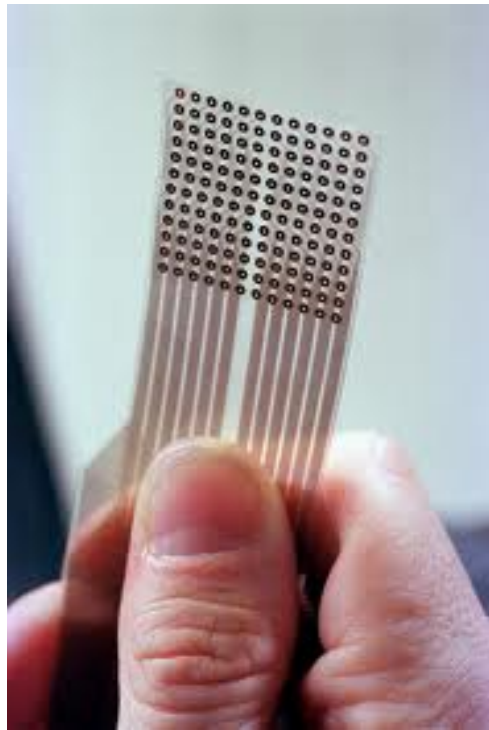
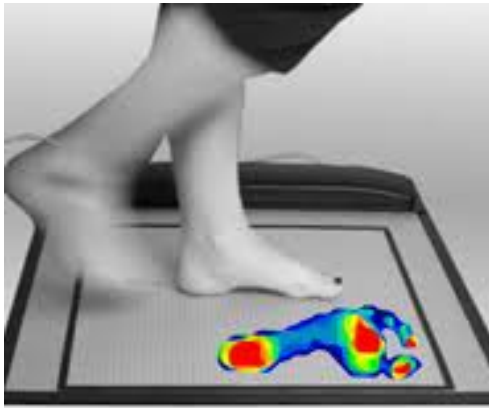


Figure 5 A cochlear implant converts sound to electric impulses for delivery to the auditory nerve. A microphone captures sound on the sound processor (a). A sound processor converts sound into detailed digital information (b). A magnetic headpiece sends the digital signals to the cochlear implant (c). The cochlear implant sends electrical signals to the hearing nerve (d). The hearing nerve (e) sends impulses to the brain, which interprets the impulses as sound (courtesy Advanced Bionics).

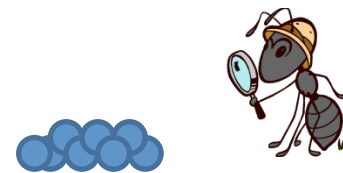


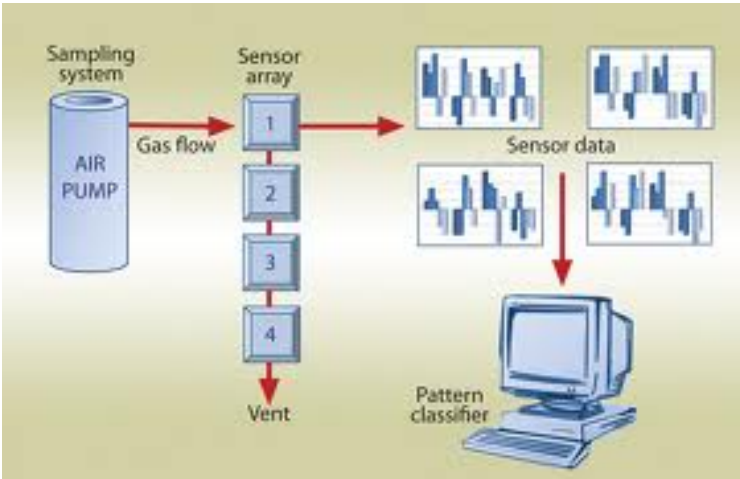
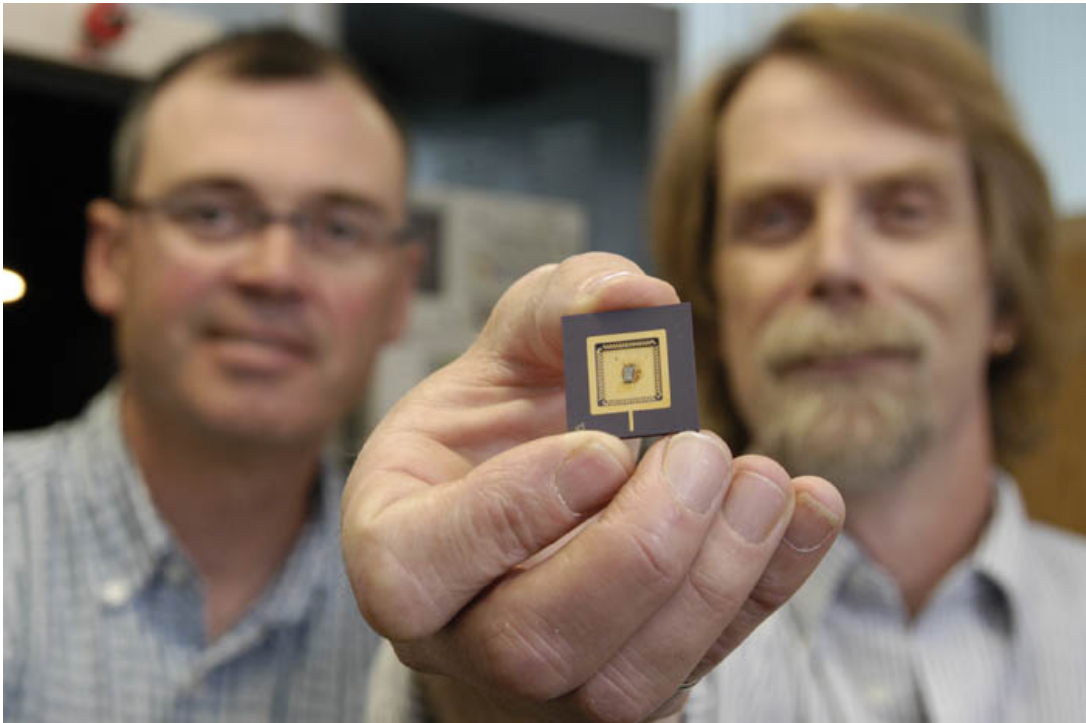


Nanosensors



If I want to measure something small, I need something small...

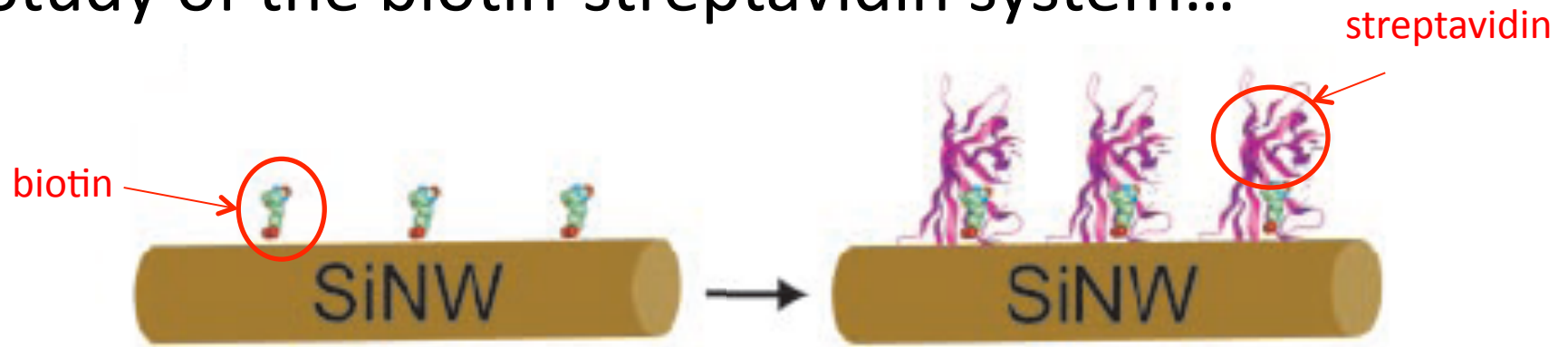




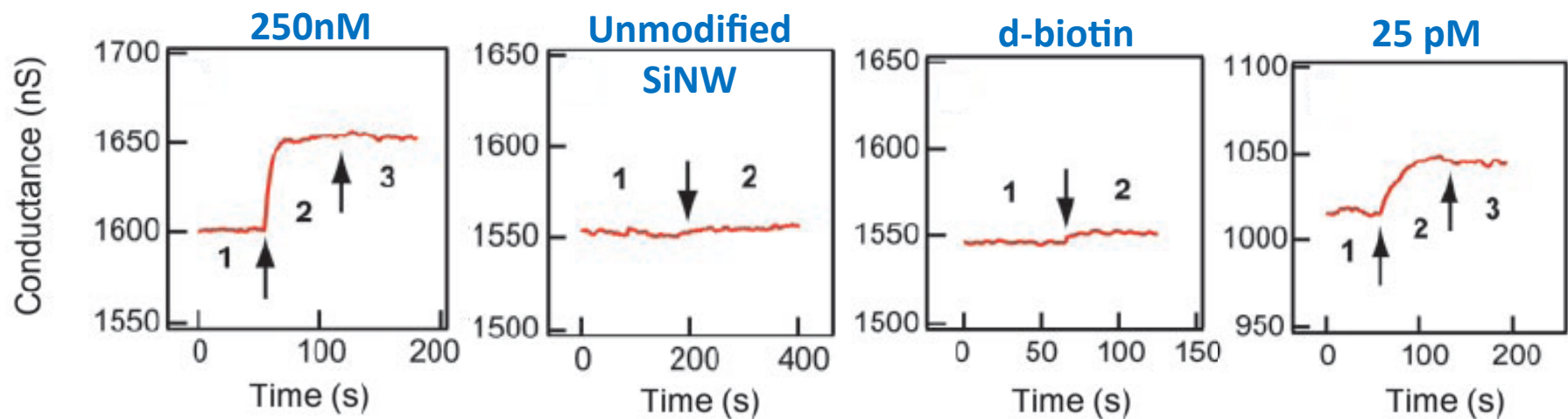


Antibody sensing

Study of the biotin-streptavidin system...



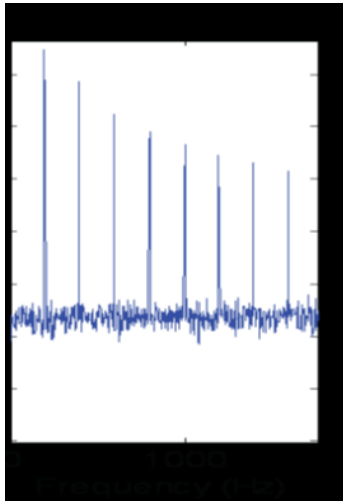
Science **293**, 1289, 2001



Acoustic biochemical sensors

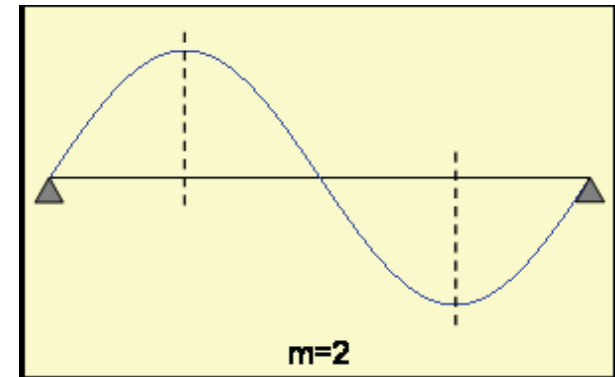
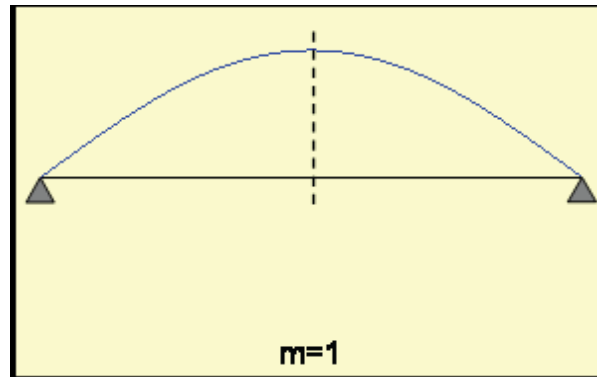
Acoustics fundamentals

- Structures can amplify (and attenuate) sound sources substantially



Modes of resonance

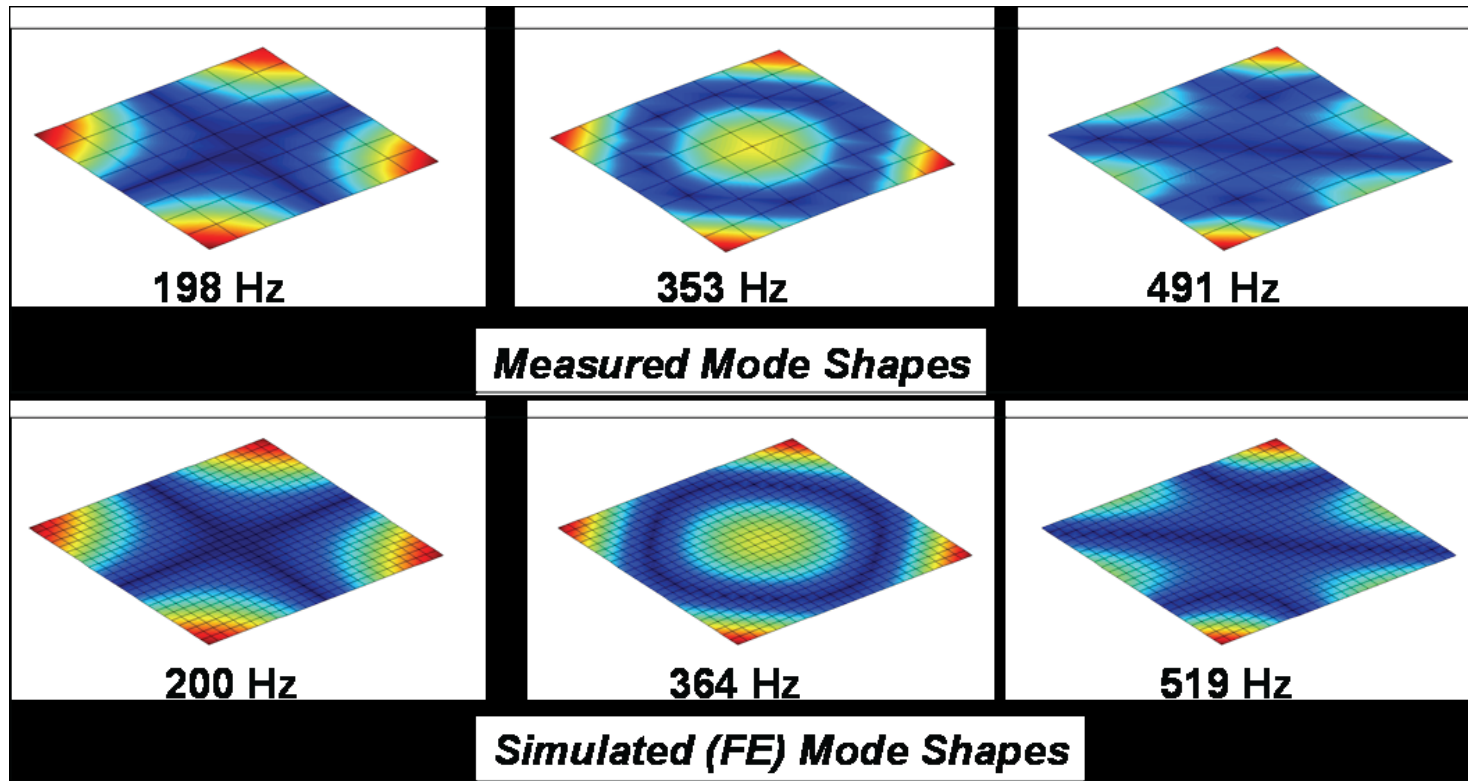
- Superposition of forward and backward traveling waves
- Example for flexure of simply supported beam:



Modes of Resonance

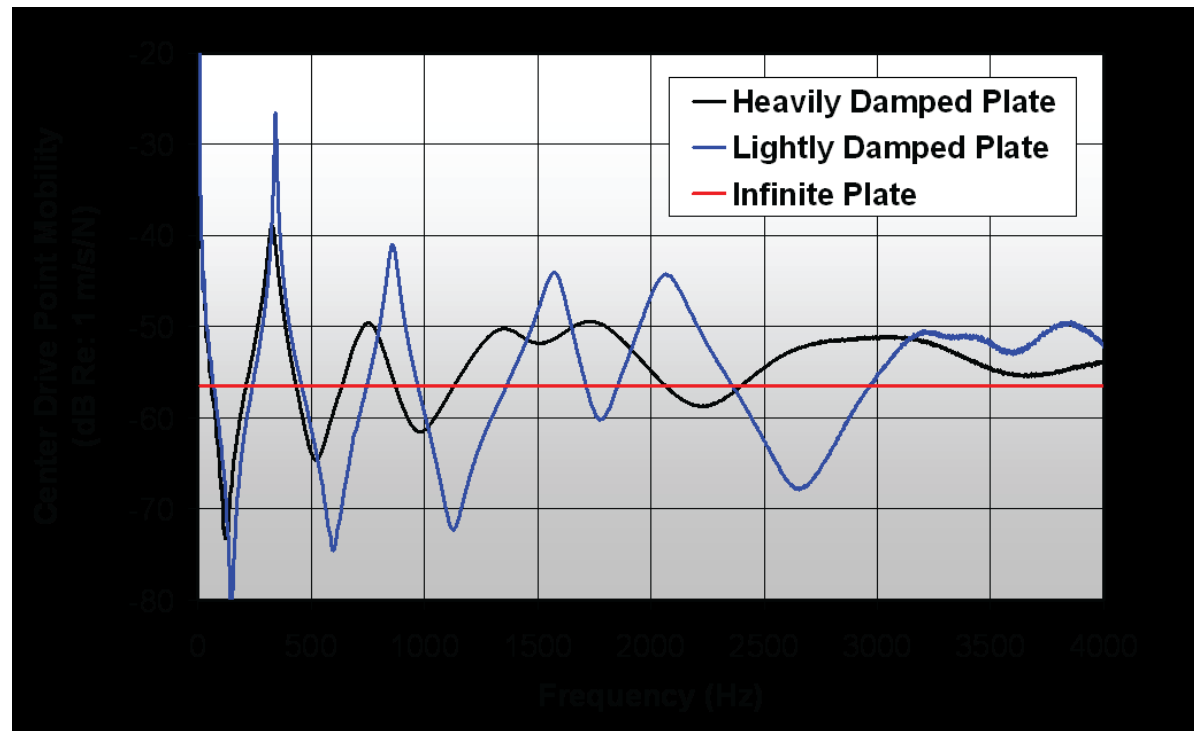
Glass plates with free boundary conditions

Mode shape



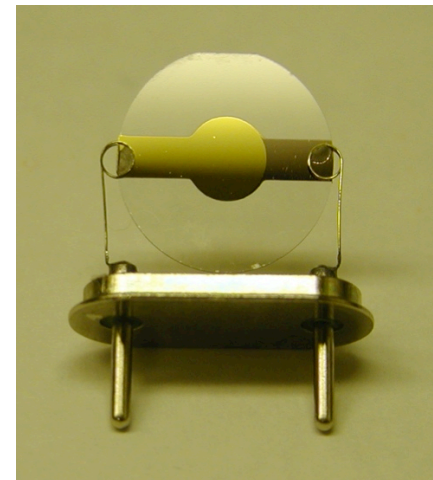
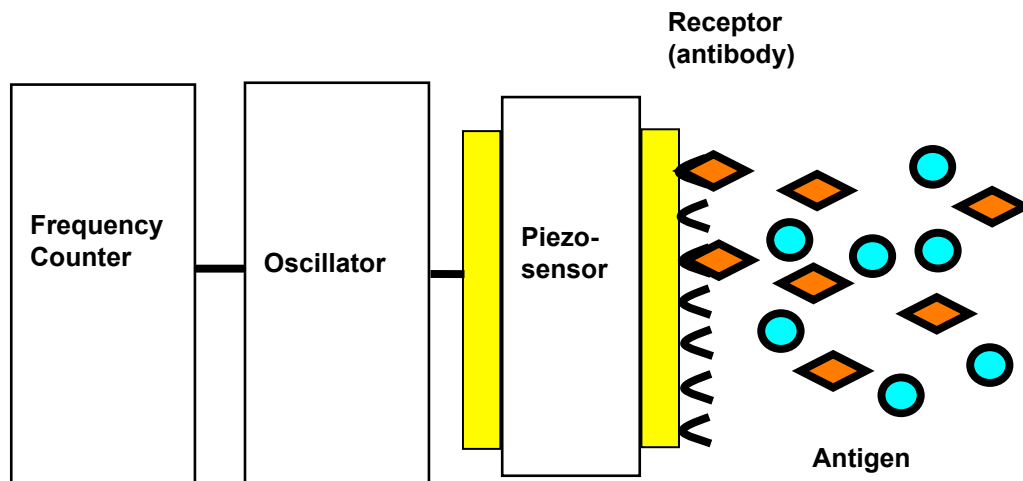
Effects of Damping on Modal Response Peaks

- Peak (and 'anti-peak') amplitudes decrease with increasing damping



Popular QCM (Quartz Crystal Microbalance)

- Capable of measuring surface mass changes on a sensitive surface area
- Large molecules (proteins, viruses and bacteria) can be measured directly after binding to the receptor (e.g. antibody)
- Limited in the sensitivity



Quartz vs. PMN-PT

Quartz = SiO_2

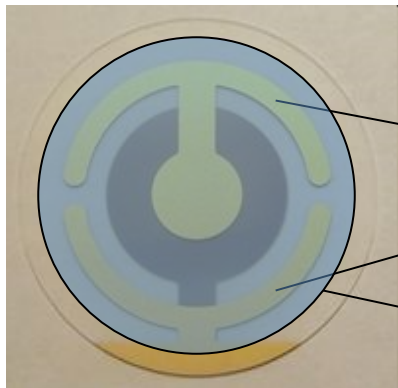


http://www.mineralminers.com/html/phantom_quartz_crystal.htm

PMN-PT = $(1-x)\text{Pb}(\text{Mg}_{1/3}\text{Nb}_{2/3})\text{O}_3-x\text{PbTiO}_3$



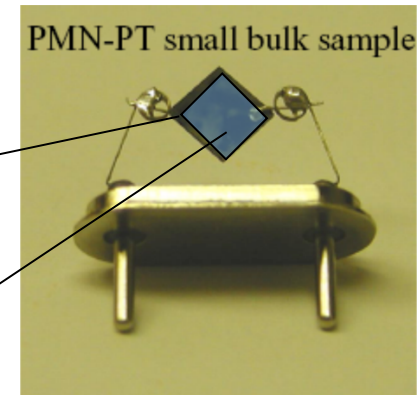
http://www.trstechnologies.com/Products/Single_Crystal/piezo_crystals.php



Au electrode
(Non-functionalized layer)

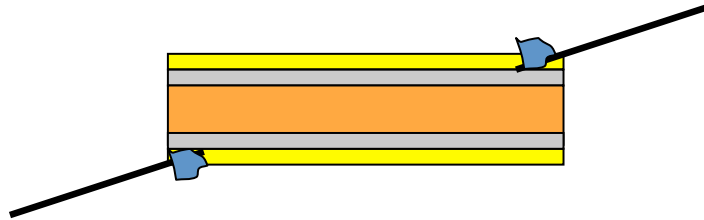
Polymethylmethacrylate (PMMA)
(Functionalized layer)

http://www.tangidyne.com/liquid_monitoring_crystals.html

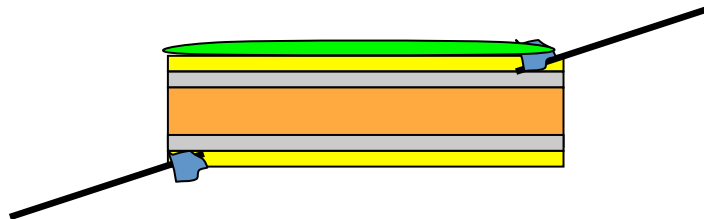


Hong, Y.K.. et al. (2004)

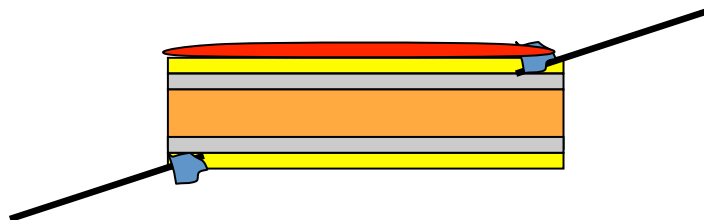
PMMA Functionalization of PMN-PT/QCM



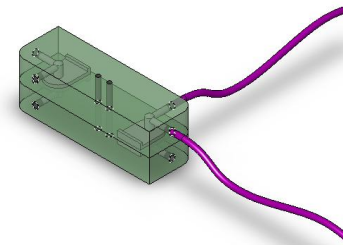
Non-functionalized PMN-PT microbalance is mounted to a spin-coater



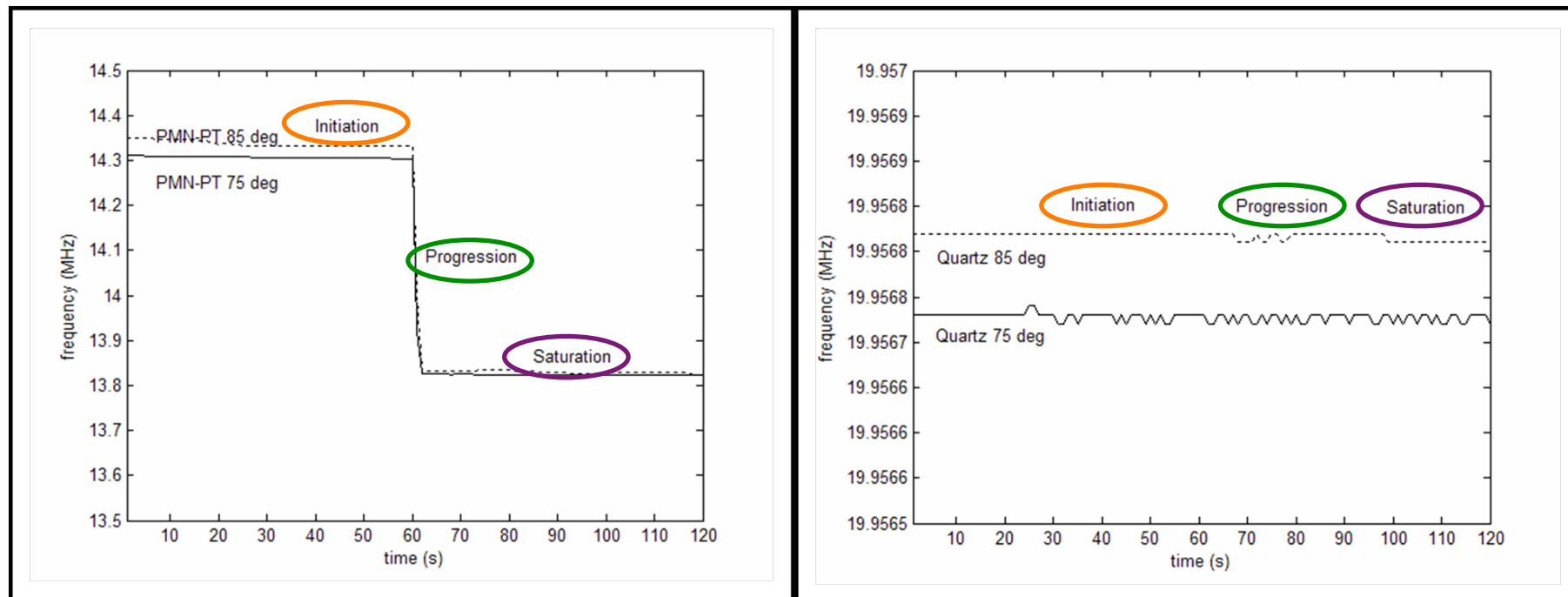
PMMA solution is spin-coated onto the electrode sensor surface



PMMA functionalized layer bakes inside oven for 30 minutes at 120 °C



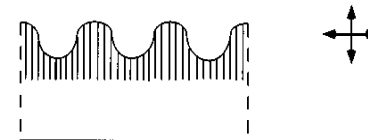
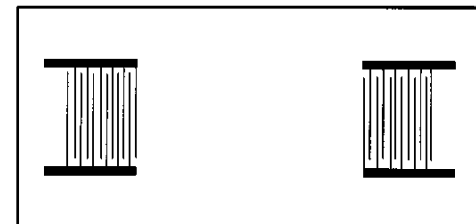
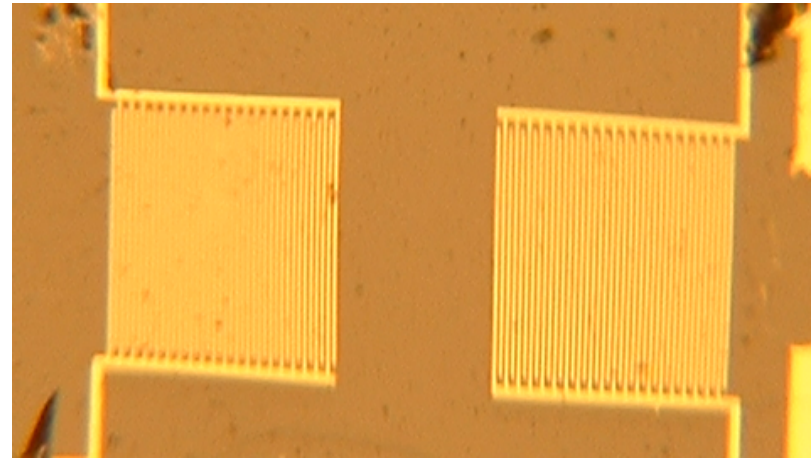
Acetone Exposure to Non-Functionalized PMN-PT/QCM



Resonator Material	Run #	Avg. Frequency (MHz)	Max Frequency (MHz)	Min Frequency (MHz)	Difference	Difference (%)
PMN-PT	1	14.50989	14.54934	14.47883	39.72 kHz	0.275
	2	14.45419	14.46916	14.42944	70.51 kHz	0.485
QCM	1	19.95673	19.95673	19.95672	10 Hz	5.01×10^{-5}
	2	19.95689	19.95690	19.95688	20 Hz	1.00×10^{-4}

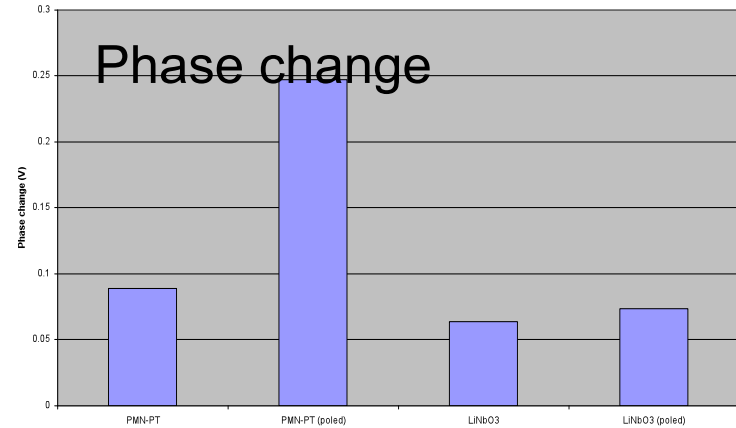
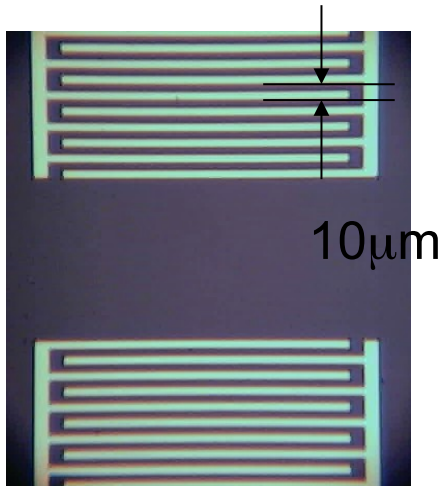
surface acoustic wave (SAW) devices

- Piezoelectric substrate, typically quartz or LiNbO_3
- Two interdigitated transducers formed by photolithographic patterning of a thin metal layer
- The frequency of a SAW device is determined by the 'finger' spacing of the IDTs
- Change in phase/frequency of the acoustic signal
- The velocity and attenuation of the propagating wave are very sensitive to properties such as mass .



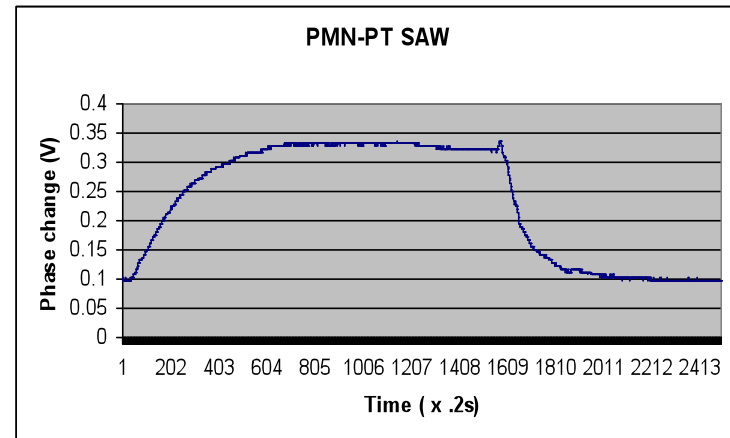
PMN-PT SAW test

Resonant frequency: 34MHz



PMN-PT

LiNbO₃



PMN-PT surface mode acoustic resonator – gas loading design (array)

