

Thin Film Active Materials

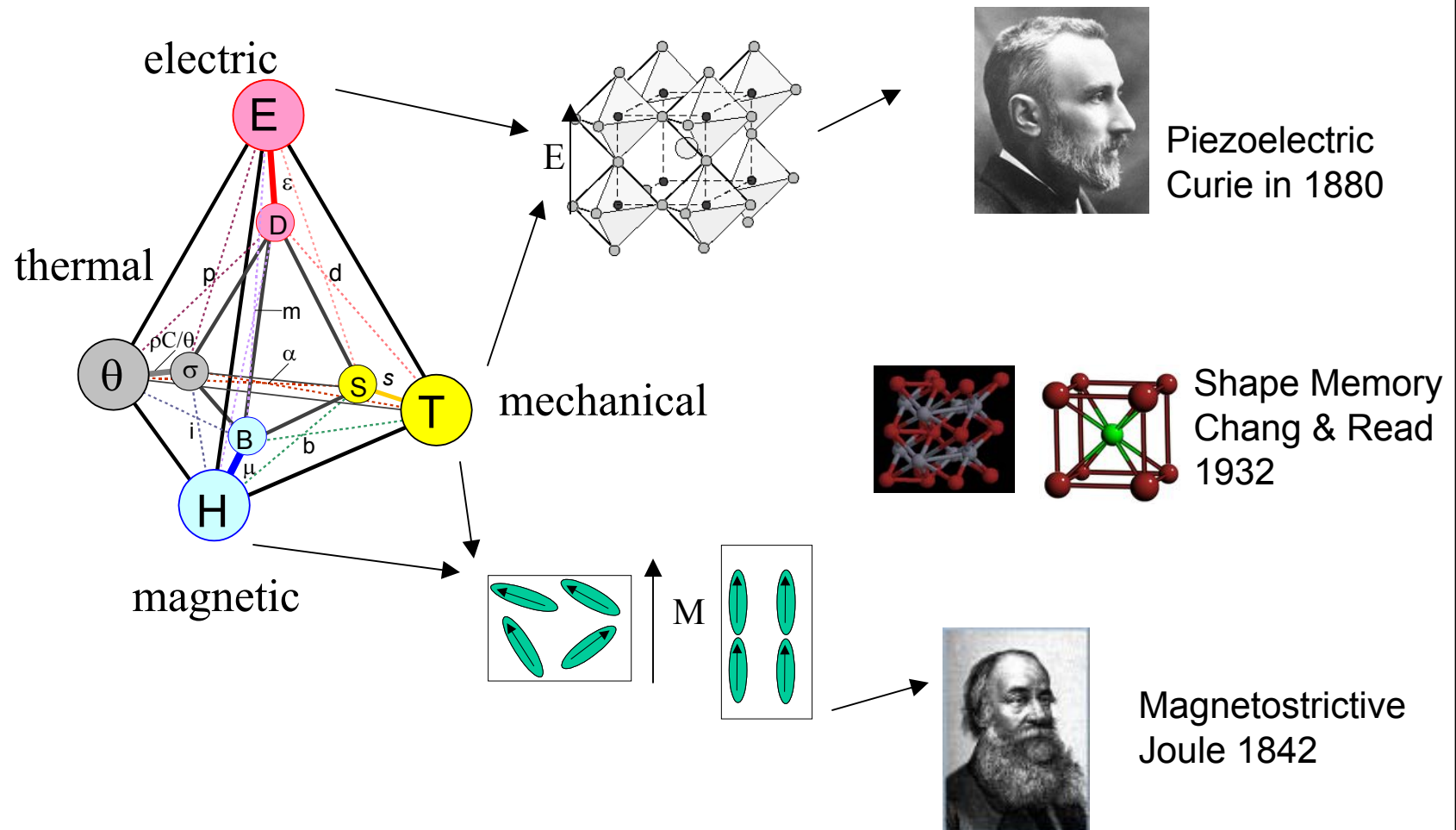


Greg P. Carman
<http://aml.seas.ucla.edu>

“An expert is a man who has made all the
mistakes which can be made in a very narrow field”

Edward Teller

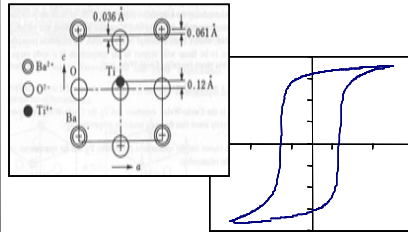
Active Materials - Definition - Coupling



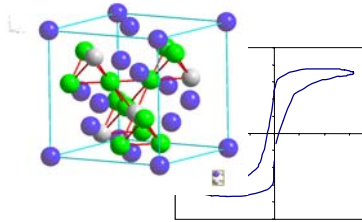
Multiferroism termed by Schmid, Ferroelectrics 1994

Classic Active Material Systems

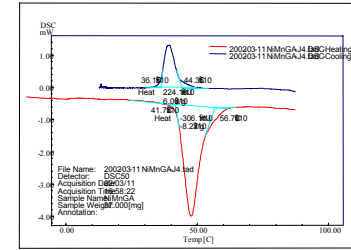
PZT



Terfenol-D



NiTi



	Strain	stress (MPa)	Specific Power (W/kg)
Piezo	0.2%	20	200-20,000
Magn	0.1%	20	140-15,000
Shape memory	4%	200	200

120,000

NiTi thin film 1990



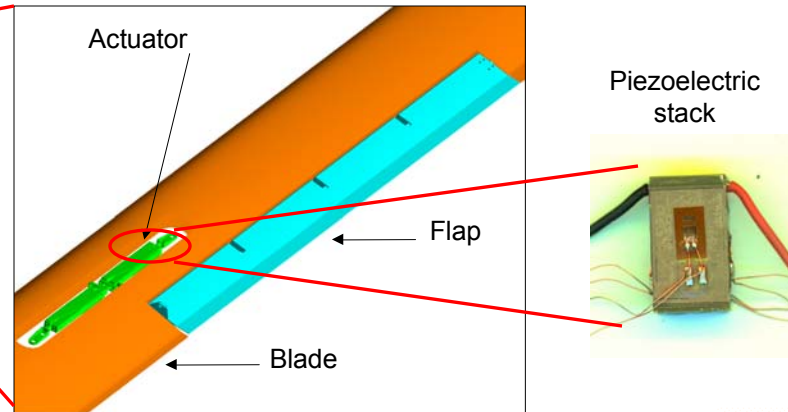
THIN FILM <10 MICRONS

- Exchange coupling interaction
- Large resonant frequencies
- Increased surface to volume ratio

Macroscopic Applications (1980's)



ACTIVE FLAP ROTOR

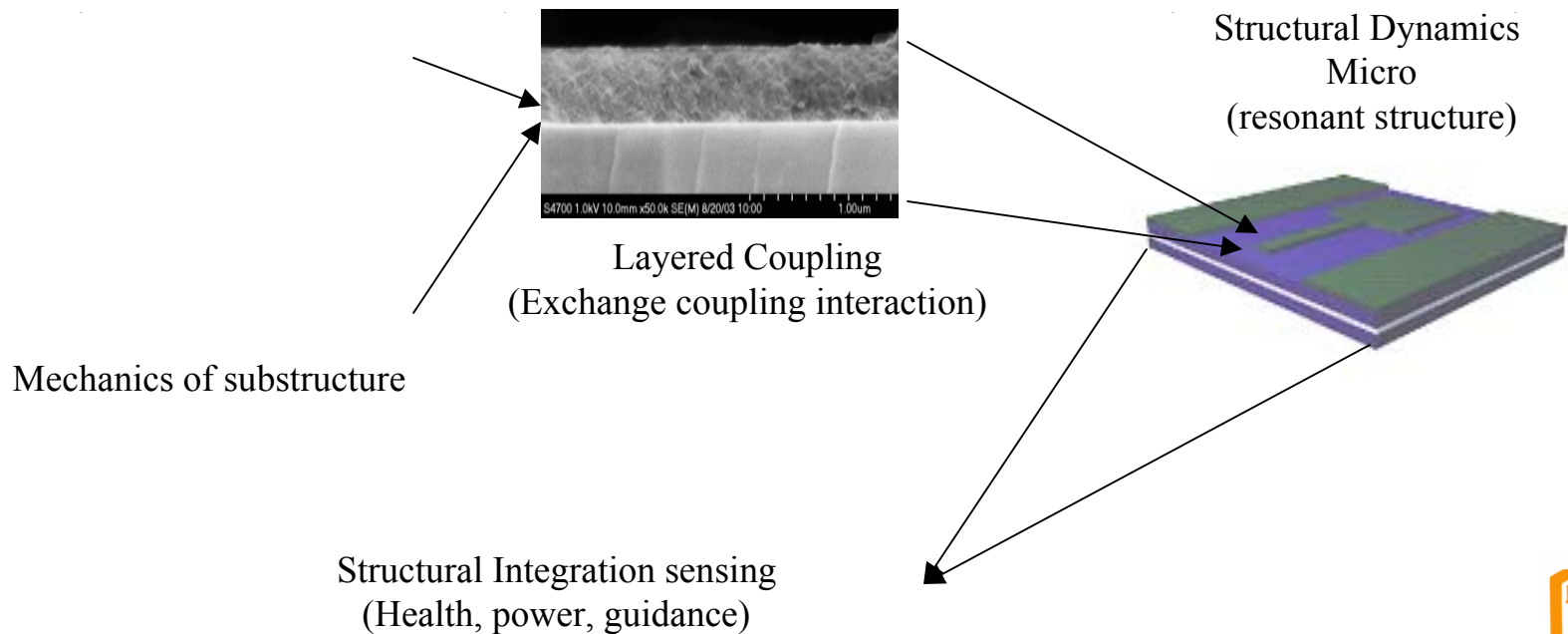
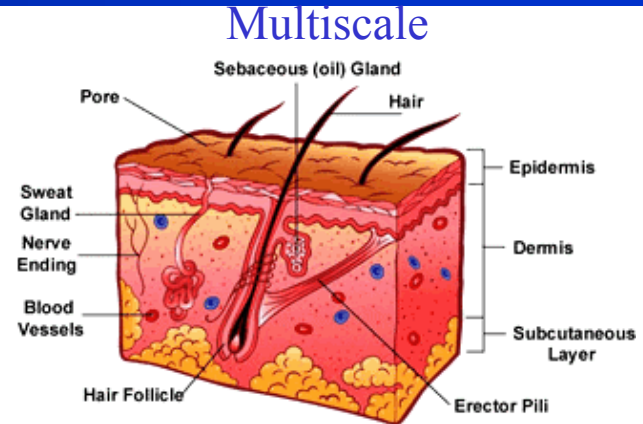
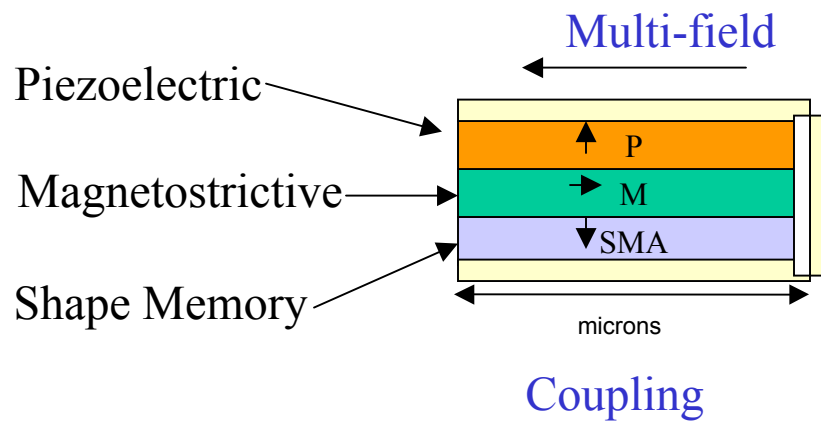


Whirl Tower Test

Boeing – Straub et al. 2000's
Active Materials Lab

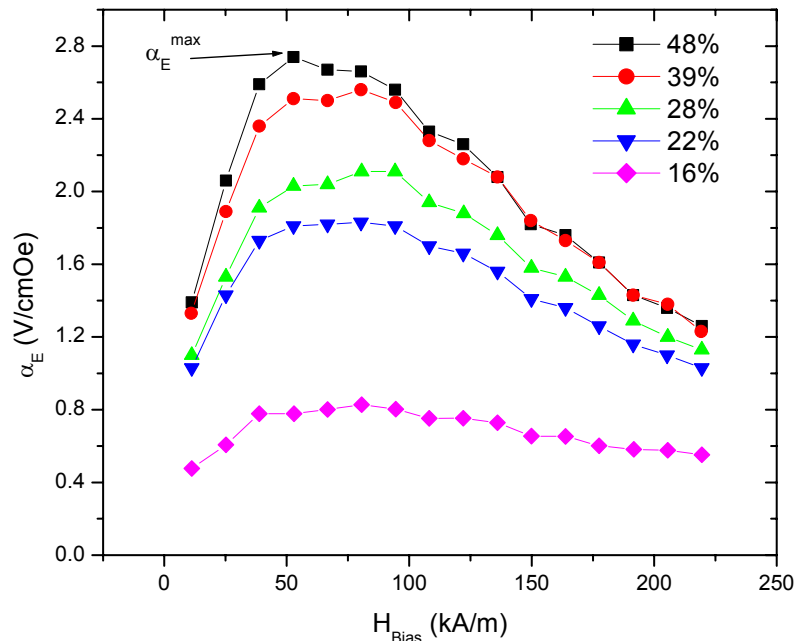
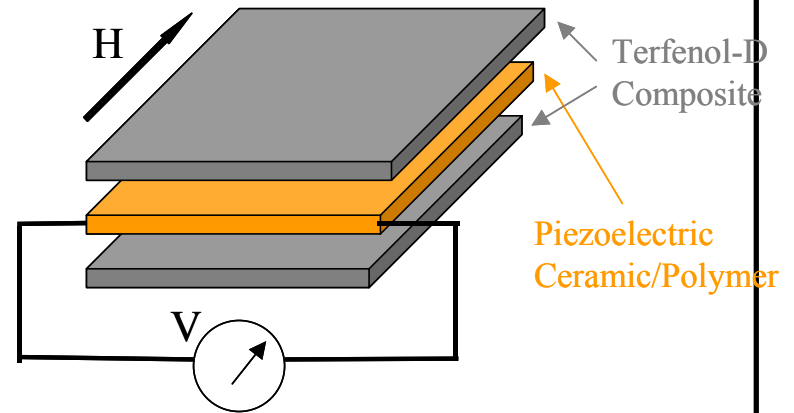
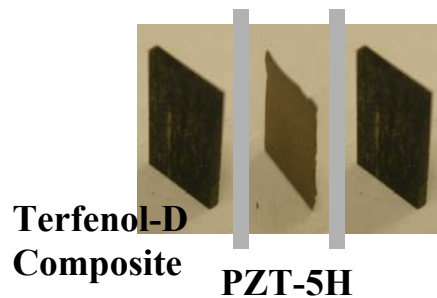


Building/Designing Sensors/Multiscale



New Thin Film Magnetometers

- Input magnetic energy
- Output electrical energy

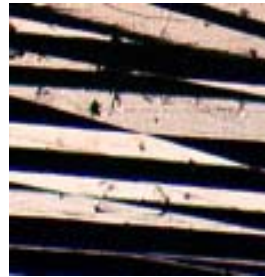


Thin film

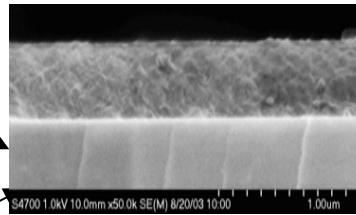
- Exchange coupling interaction
- Large resonant frequencies
- Inexpensive

Inventory Tracking

Energy Harvesting (mechanical-thermal)

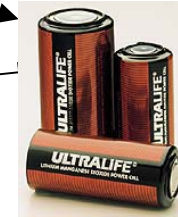


Mechanics of Phase Transformation
micro



Coupled Structure (convert to electrical)

Structural Dynamic
recharger

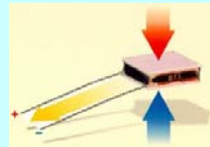


Solar or Vibration energy to
Electrical Power



Solar Panel

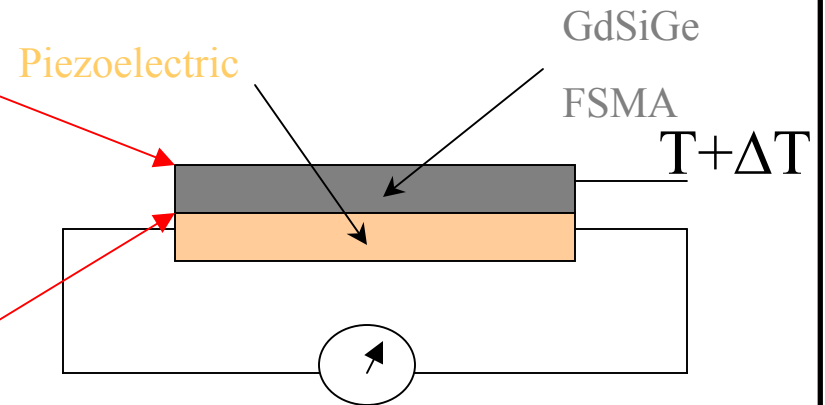
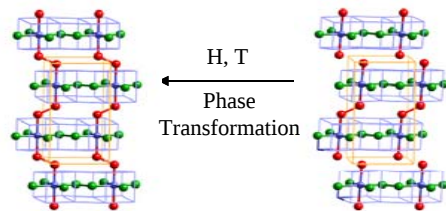
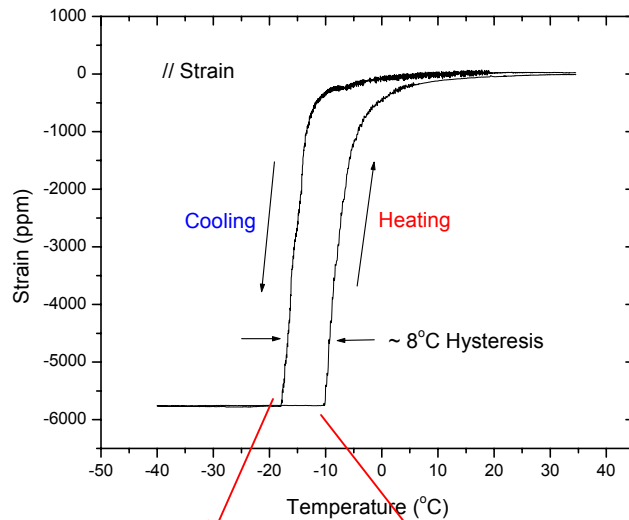
Thermoelectric
Generator



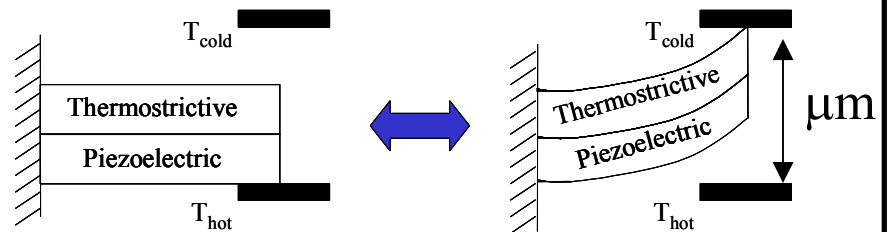
Drawbacks

- Low Efficiency
- Low Power Density (on volumetric or mass basis)

Energy Harvesting – Waste Heat



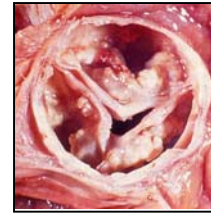
Thin Film
(kHz frequency)



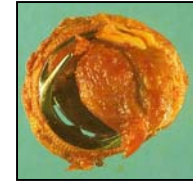
Biological Replacement Components

Diseased Heart Valves

- Mechanical or bioprosthetic artificial valves
- Requires invasive open heart surgery to implant
- Tissue valves only last 5-15 years
- Mechanical valves require anticoagulants to prevent blood clots

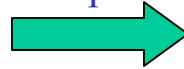


Diseased
Heart valve

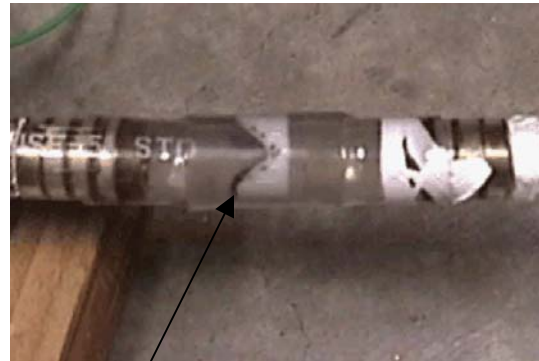
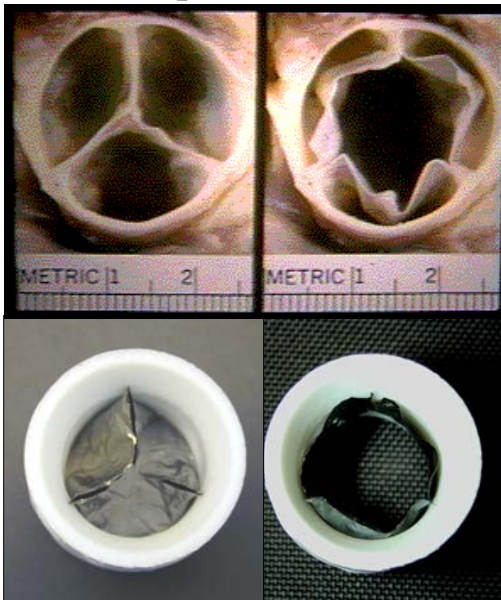


Blood clot on
mechanical valve

Percutaneously placed
outpatient

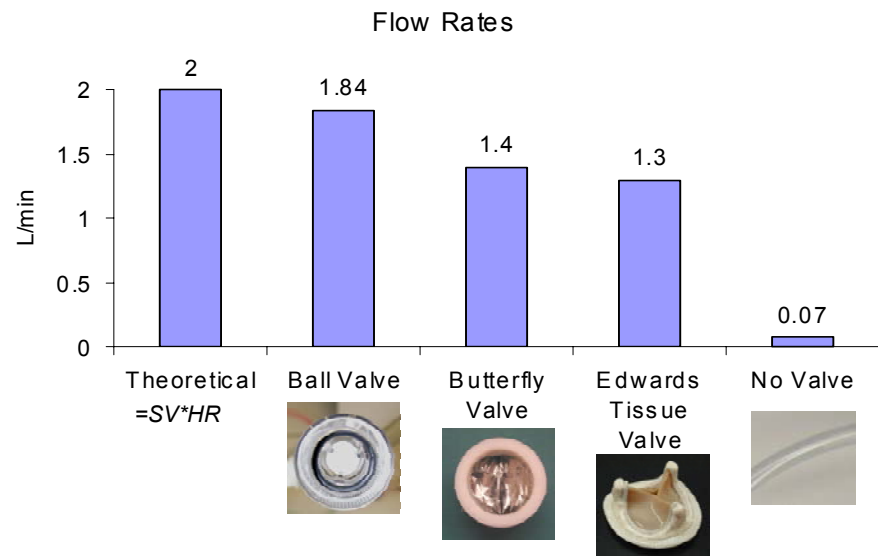
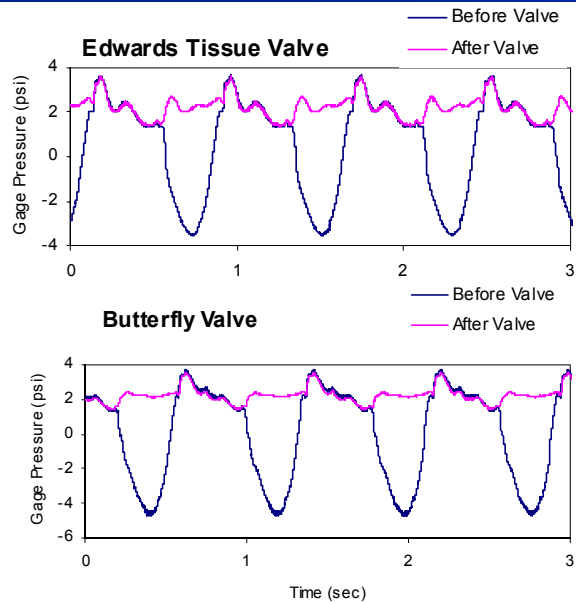


NiTi Replacement valve

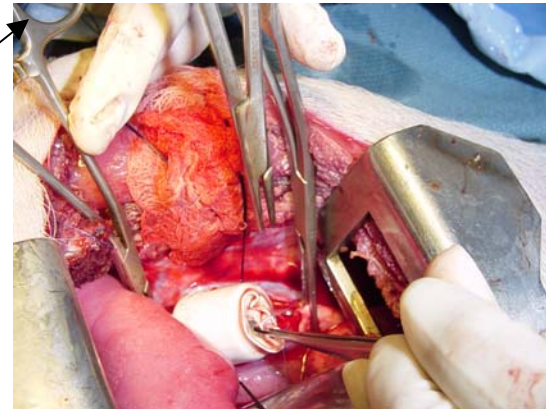


NiTi thin film

Test Results Thin Film Heart Valve



Animal Testing

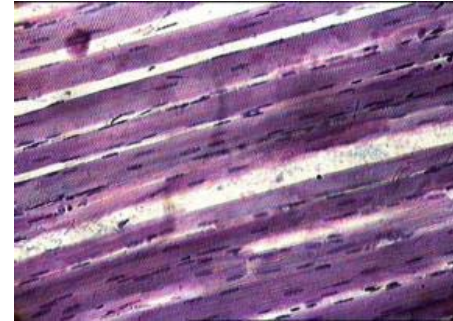


Actuators – Future Miniaturization

Miniaturization

Micron/millimeter scale
Power density metric
Thin film active materials

Multi-assembly



Actuator Requirements

- Force – F
- Displacement – d
- Response – f
- Size – m

Thin Film Active Materials

10,000-100,000
Watts/kg

PZT – Terfenol-- SMA

Conventional Motors

specific power decreases with
size



100
Watts/kg

Specific Power = $F \cdot d \cdot f / m$

Active Materials Lab

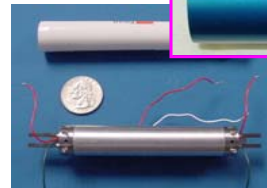


Beginning - Active Material Motors

Actuator	Specific Power Density (W/kg)
Electromagnetic Motor –fist size	~ 200
SMA Pump *	100 (1000)
Piezohydraulic Pump *	160 (1000)
Burleigh Piezoelectric Linear Motor *	20 (100)
Piezoelectric Ultrasonic Motor *	140 (700)
UCLA Mad Device	140
Piezoelectric Inchworm	~ .05



Kinetic ceramics



Burleigh

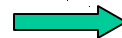


Conventional motors
Win in the large scale
(bigger than a fist)



Future lies in smaller (milli-micro-nano) scale systems

MACRO



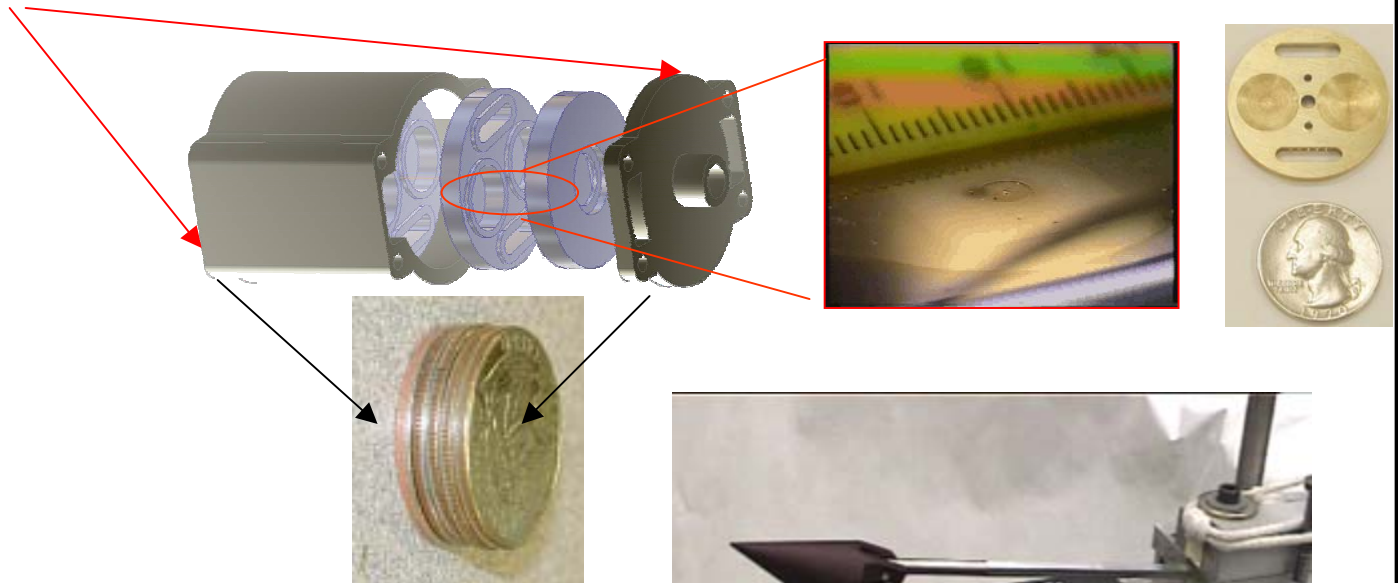
Active
Thin Films



MICRO-NANO

Thin Film NiTi Motor

100Hz – 125 kW/kg film



Need

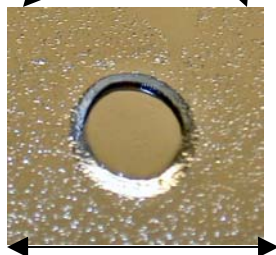
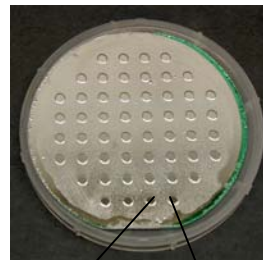
- Compact actuation missile guidance



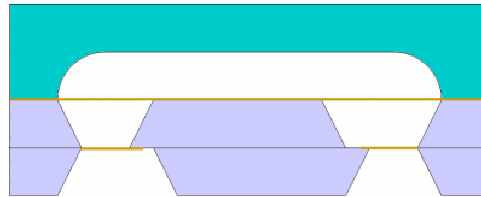
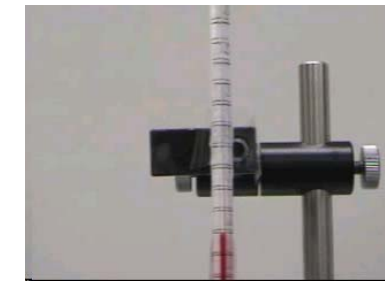
Small Motors Required – Artificial Pancreas

Current technologies

Future



1mm



NiTi Pump Actuator

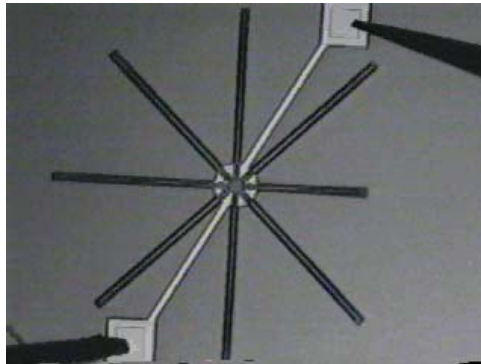
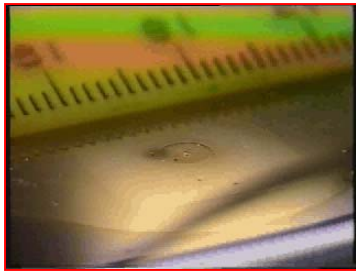


Active Materials Lab

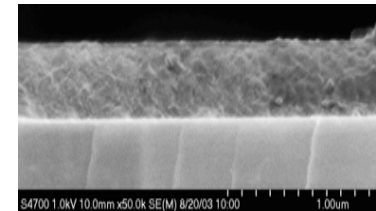


Summary

- Thin film active materials (e.g. NiTi, piezoelectric ..) relatively new area of study
- Opportunities (multiscale & multifield) exist to design entirely new systems
- Actuation systems offers enormous opportunities in the small scale (microns), revolutionary concepts
- Multitude of biological, commercial, and defense applications exist for the area



FABRICATION



EVALUATION

Notable Quotes



“No other kind of thought except intuition is more accurate than scientific knowledge.” **Aristotle**



“Most of the things worth doing in the world have been declared impossible before they were done.”

Louis Brandeis