Self-powered nodes and Bio-Sensing

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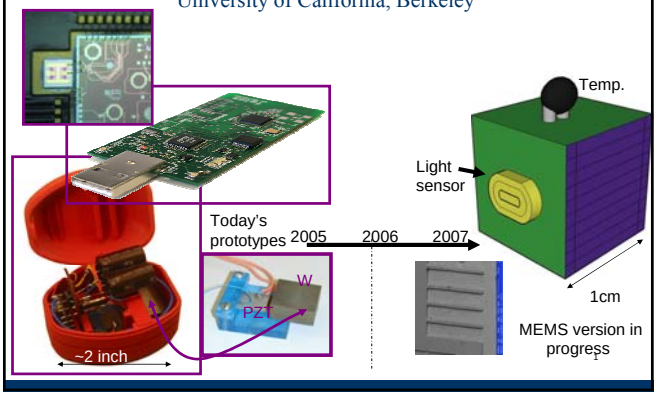

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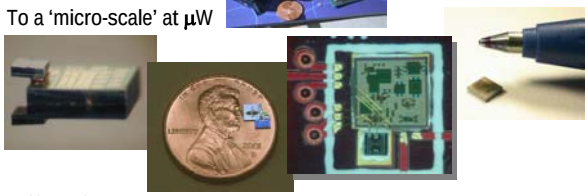
Technology Platforms for Pervasive Computing

From a 'meso-scale' running at milliwatts

To a 'micro-scale' at µW



Adapted from Various Sources:
E.g. Ember, Crossbow, K. Pister, J. Rabaey, D. Culler…

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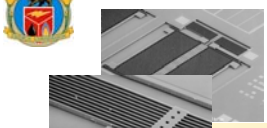
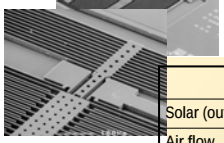
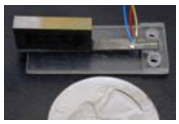
Design Question: What energy can one harvest in 1 cm³?







	µW/cm³
Solar (outside)	15,000
Air flow	380
Human power	330
Vibration	200
Temperature	40
Pressure Var.	17
Solar (inside)	10

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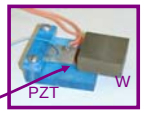
Vibration-Based-Scavenging

Sources
- HVAC ducts
- Raised Floors
- Motors
- Large windows
- Mount under wooden staircase



- **Three Rules for Design**
  - $P \sim M$
  - $P \sim A^2$
  - $P \sim 1/\omega$
- **PZT-shims with W-mass**
  - Early work ~ 800 µW/cm³ at 5 m/s² (on a clothes dryer!)
- **Recent successes**
  - TinyTemp Node on stairs
  - MEMS piezo bender

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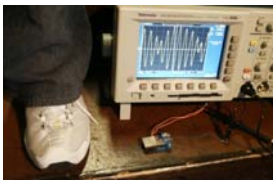
TinyTemp/TinyOS Node



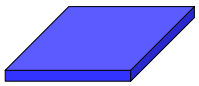
- Stair-Case Vibrations from Running Up and Down Stairs
- Piezoelectric: PZT
- Tungsten Alloy Mass: 52 g
- Beam Dimensions:
- 1.25" x 0.5" x 0.02"
- Resonant Frequency: 26.8 Hz
- Power Output: 450 µW

"Most challenging issue"

- **Reduction to MEMS**
- **Miniaturization while maintaining sufficient energy scavenging to power the next generation low power radios**

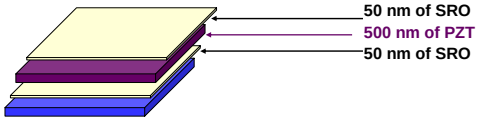
Microfabrication

- **Base layer of Si/STO ($SrTiO_3$) provided by Motorola**

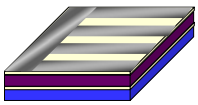


- •Si provides ease of fabrication
- •STO enables epitaxial growth

- **SRO ($SrRuO_3$) PZT ($PbZr_{0.53}Ti_{0.47}O_3$) deposited via PLD**



Deposition and patterning



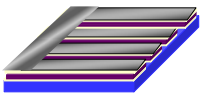
Edwards electron beam evaporator

* Ti: 10-15 nm (for adhesion purposes)

* Pt: 150-200 nm

→ Pt thickness will be varied to function as elastic layer….

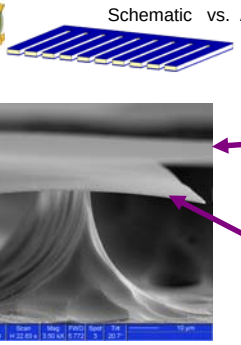
- **Initial etching**

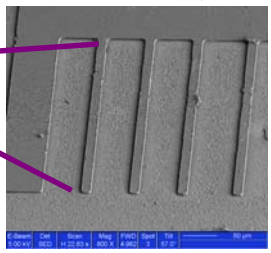


Ar Ion mill

* 5 nm/min @ 0.25 mA

Schematic vs. Actual Device



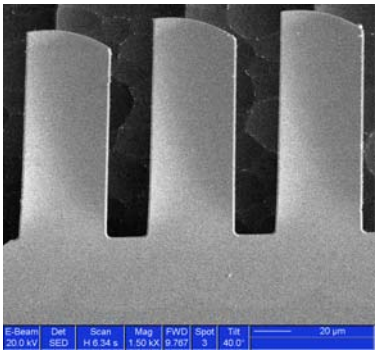


End-on view of one MEMS cantilever

View from above of MEMS cantilevers…

PhD Research of Eric Carleton, Elizabeth Reilly

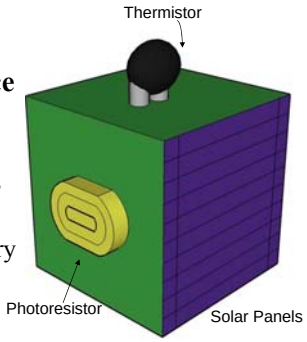
Our best MEMS example to date…



Eric Carleton and Beth Reilly (PhDs)

Design for Monolithic Integration "The PicoCube"

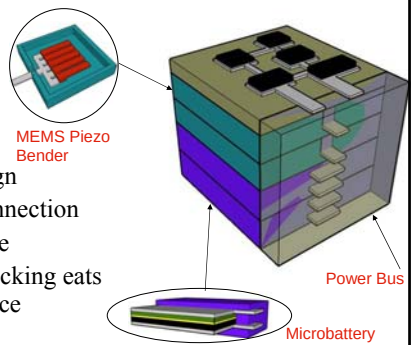
- **Conceptual thinking about integrated device at a size of ~1 cm³**
  - 3-D wiring
  - 4 sides with solar panels
  - 2 sides with sensors
  - On-board recharg. battery
  - On-board piezo electric generation



PhD Research of Dan Steingart, Eric Carleton, Elizabeth Reilly, Brian Otis, Mike Seeman, Nate Pletcher

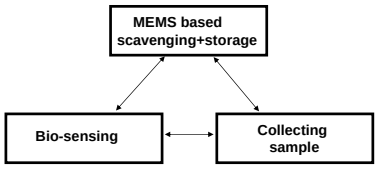
Details

- **≥ 3 Separate Components**
- **1 Bus**
- **Overall**
  - \+ Modular Design
  - \+ Simplifies Connection
  - \- Steals a surface
  - \- Component packing eats significant space



PhD Research of Dan Steingart, Eric Carleton, Elizabeth Reilly, Brian Otis, Mike Seeman, Nate Pletcher

"Bio-Piconodes"



Biosensor:

- Small, integrated, low-cost, low-power sensor
- Produces an electronic signal in proportion to an analyte (0_2, glucose etc.) or local condition (pH, temperature etc.)

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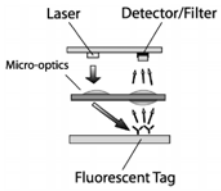
Towards Low-Power Bio-Sensors

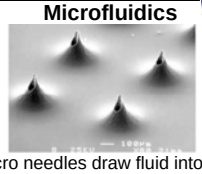
Fluorescence Microscopy



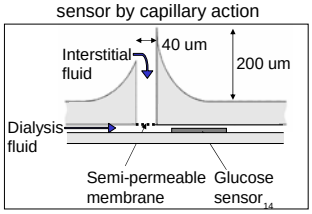
At 2mW, the VCSEL (Vertical Cavity Surface Emitting Laser) produces 100nA signal for 100uM sample

STANFORD: Modified from Thrush, 2003

Microfluidics



Micro needles draw fluid into a 3-electrode enzyme-based glucose sensor by capillary action



BERKELEY: Modified from Liepmann, 2003

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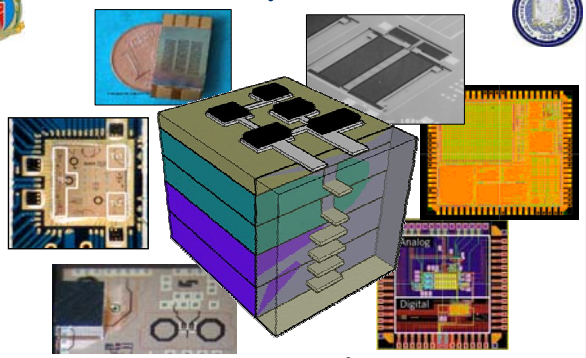
End/Summary/Questions



Advanced 2.5 packaging: the answer to mm³ nodes + the design trade-offs based on source, storage, duty-cycle, sensors

P. Wright, Jan Rabaey, S. Sanders, James Evans
Also: Infineon, Agilent

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