Microsystems Technology Labs:

a MEMS (and other devices) Fabrication Facility

Dr. Vicky Diadiuk
MTL Associate Director, Operations
Massachusetts Institute of Technology

MTL Mission

- Support EDUCATION (graduate & undergraduate) through research in semiconductor devices and processes
- Support RESEARCH in microsystems technologies and foster new microstructure initiatives
- Provide FACILITIES and infrastructure for research in microsystems and associated technologies

MTL – Fabrication Infrastructure

- Integrated Circuits Laboratory (**ICL**)
  - Class 10 - 2800 sq.ft. (6")
  - 0.5 micron CMOS baseline process
- Technology Research Laboratory (**TRL**)
  - Class 100 - 2200 sq.ft. (6")
  - Flexible Process Environment
    - Silicon, Compound Semiconductors
    - Ceramics, Plastics, …
- Exploratory Materials Laboratory (**EML**)
  - Class 10,000 - 2000 sq.ft.
  - Thin Film Processing Facility

MTL - People

- Faculty
  - 14 'Core' Faculty
  - 73 'Affiliate' Faculty
- Staff
  - 21 Semiconductor Process Staff
  - 4 Computer Support Staff
  - 7 Administrative Staff
- Students
  - ~350-400 Associated Students

Revenues:

~$3.3 M — 40% Industrial support
60% Lab Fees

Expenses:

~$3.3 M — 55% Materials & services
45% Personnel

MTL Research Volume: ~$8M
Enabled Research Volume: ~$40M

MTL Industrial Support (MIG)

- AMD
- Analog Devices
- HP
- Intel
- IBM
- Motorola
- Novellus
- TI
- Applied Materials
- TSMC
- u-chips (MAP)

MTL Industrial Support (MIG) Member Companies

NOVELLUS

APPLIED MATERIALS™

AMD

MOTOROLA
intelligence everywhere™

tsmc

National Semiconductor
The Sight & Sound of Information

intel.

ANALOG DEVICES

IBM

hp
invent

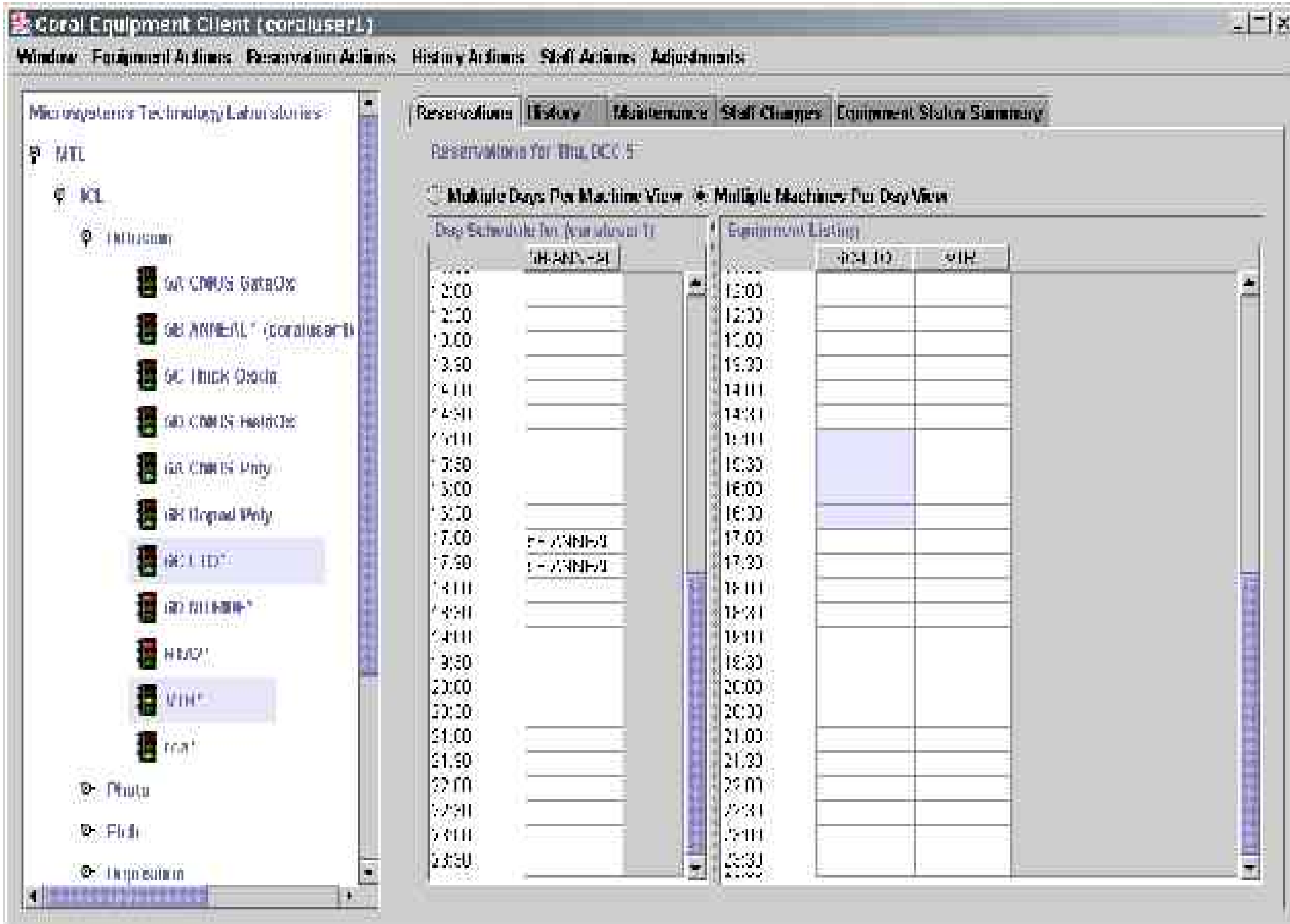
TEXAS INSTRUMENTS

CORAL

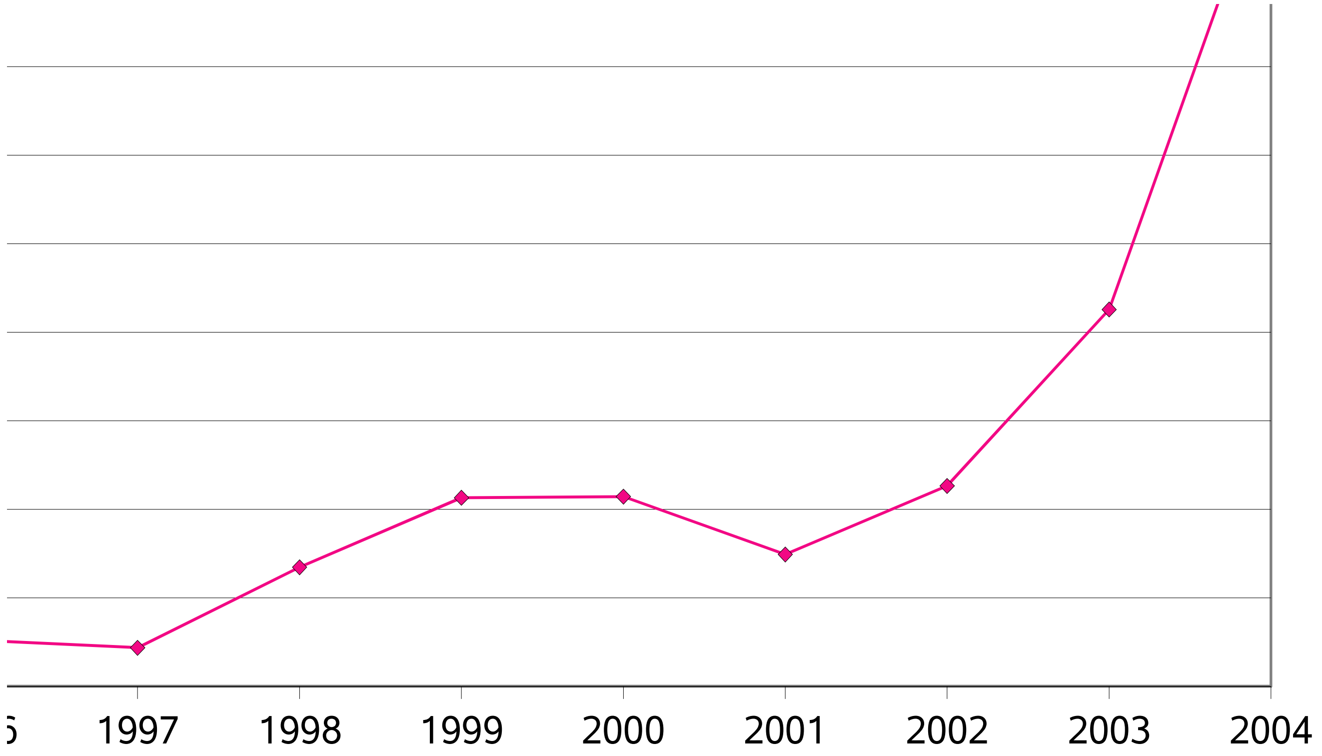
(Common Object Representation for Advanced Laboratories)

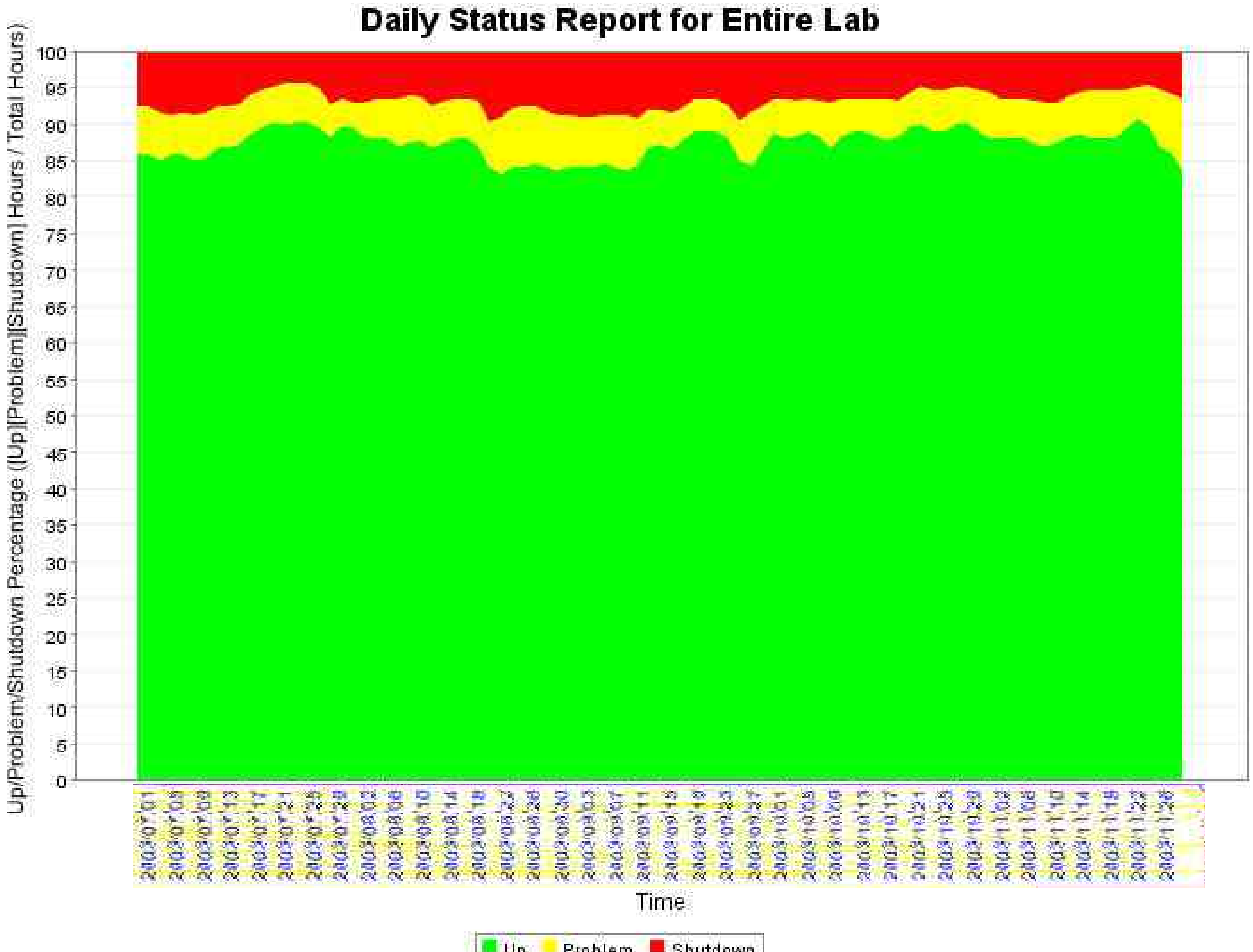
Developed jointly with Stanford, for use in University fabs

- Reservation Actions
  - Make, view, delete reservations
  - Review user daily schedule, or multi-machine view
- Equipment Actions
  - Turn on, turn off
  - Enter, review run data
  - Report problem, shutdown
  - Maintenance history/lab status
- Reporting functions
  - Usage by Machine or User
  - History Reports by Lot, User or Machine
  - Qualification logs (by Users or Machine)
  - Buddy Finder (for specific time range)
  - Accounting


Coral Equipment Client (coraluserL)
Window
Equipment Actions
Reservation Actions
History Actions
Staff Actions
Adjustments
Microsystems Technology Laboratories
MTL
Reservations
History
Maintenance
Staff Changes
Equipment Status Summary
Multiple Days Per Machine View
Multiple Machines Per Day View
Equipment Listing
Photo

Yearly Machine Units (Monthly Average)





Daily Status Report for Entire Lab
Up/Problem/Shutdown Percentage ([Up][Problem][Shutdown] Hours / Total Hours)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Time
Up
Problem
Shutdown

Major Fab Tools

- Diffusion: atmospheric & LPCVD furnaces
- Photolithography: mask-aligners, stepper
- Dry Etch: various chemistries, depth, wall angle
- Deposition: PECVD, e-beam, sputtering
- Wet Processes: clean, etch, release
- Metrology: thickness, index, morphology
- Packaging: CMP, die-saw, wire-bond

MEMS-centric Machines

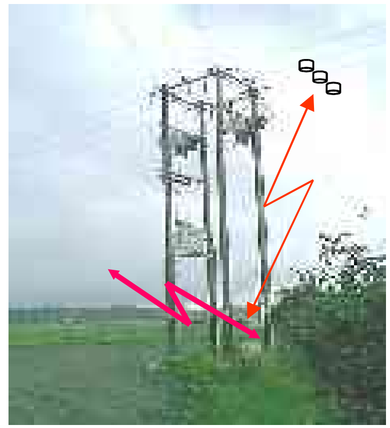
- EVG Wafer aligner-bonder
- STS Deep Reactive Ion Etching (DRIE)

Issues related to sharing a VLSI fab

- Must control contamination and particles
- Au vs non-Au machines (color-coded)
- Handling of perforated wafers

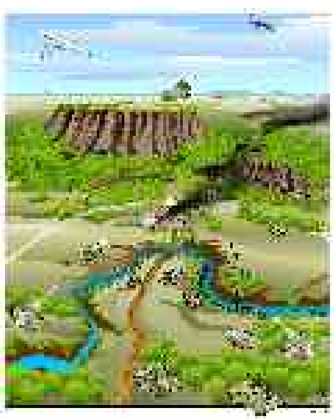
Emerging Microsensor Applications

Industrial Plants and Power Line Monitoring (courtesy ABB)



Operating Room of the Future (courtesy John Guttag)

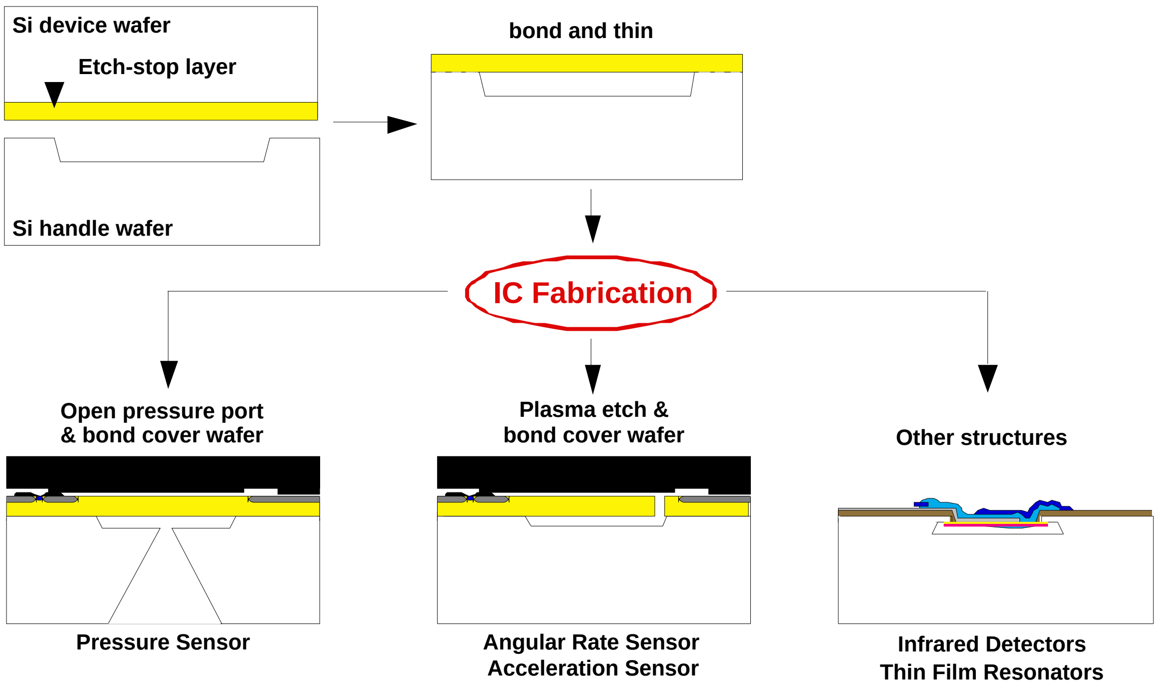
Target Tracking & Detection (Courtesy of ARL)



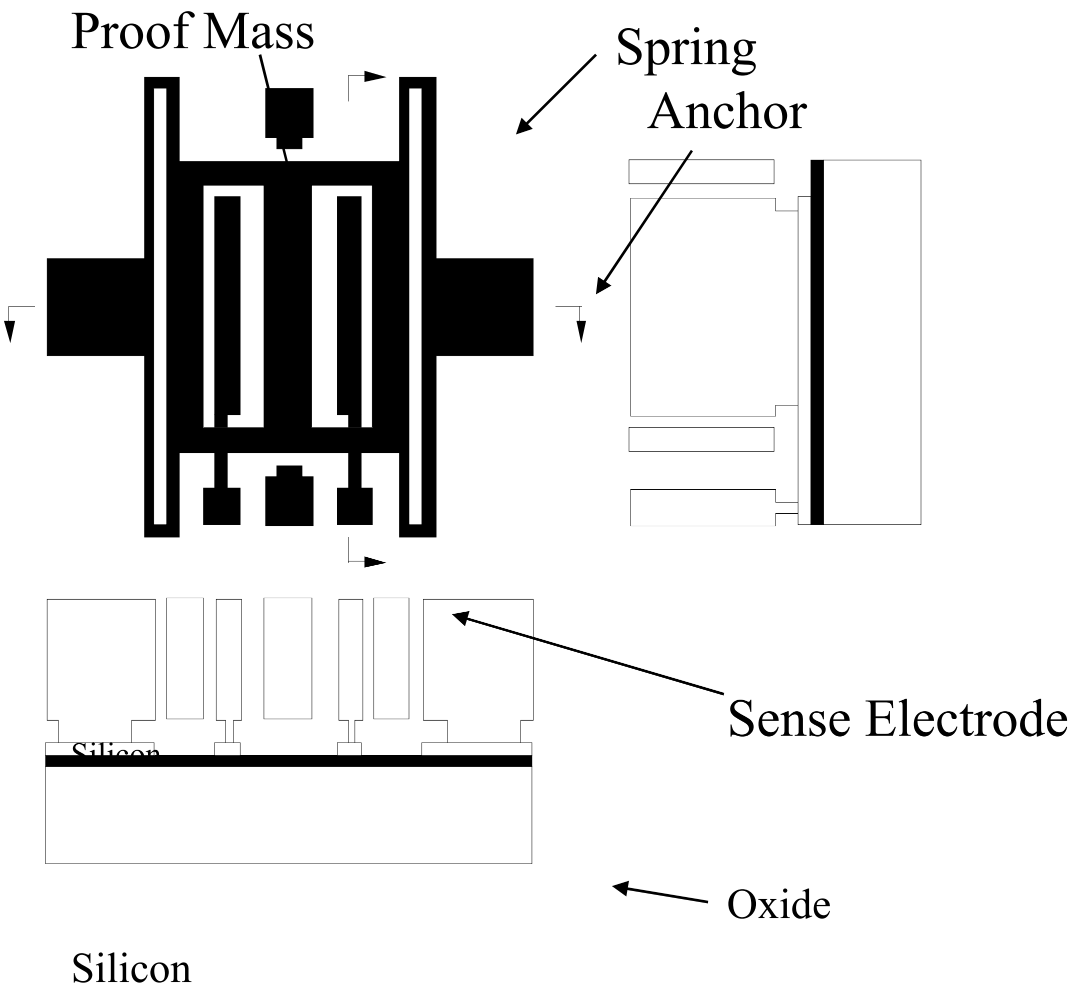
Location Awareness (Courtesy of Mark Smith, HP)

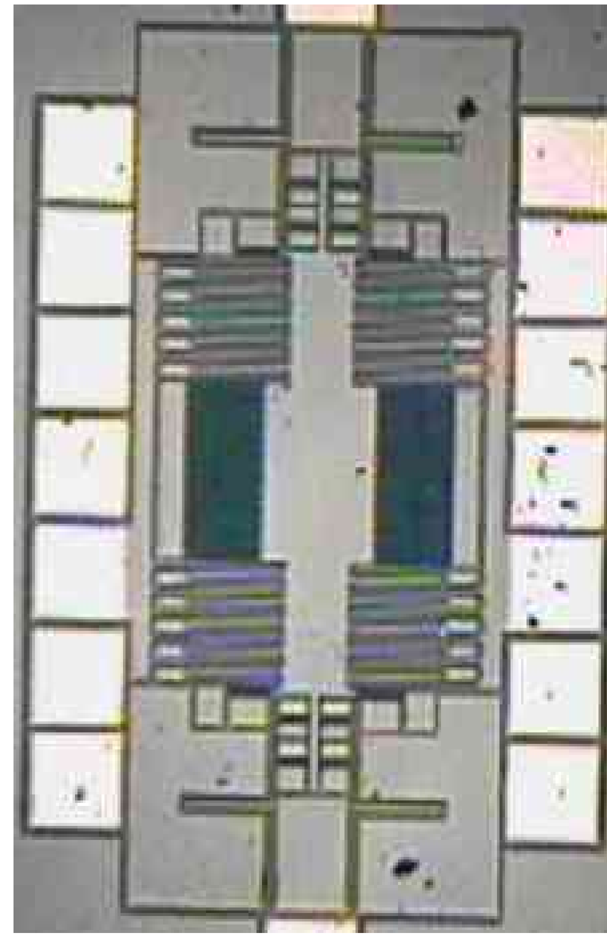
NASA/JPL *sensorwebs*

Integrated MEMS



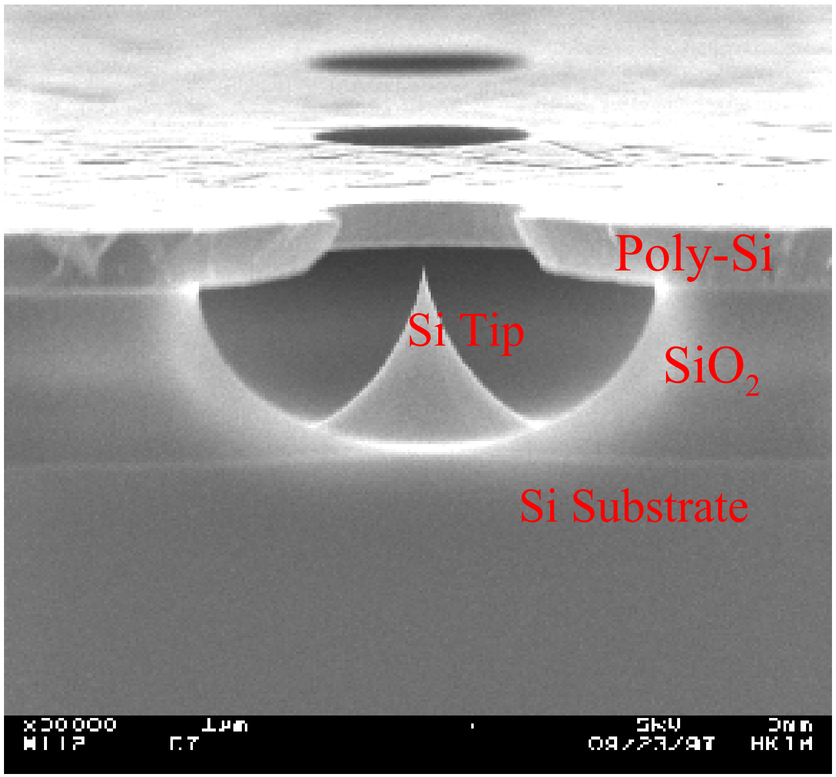
Accelerometer

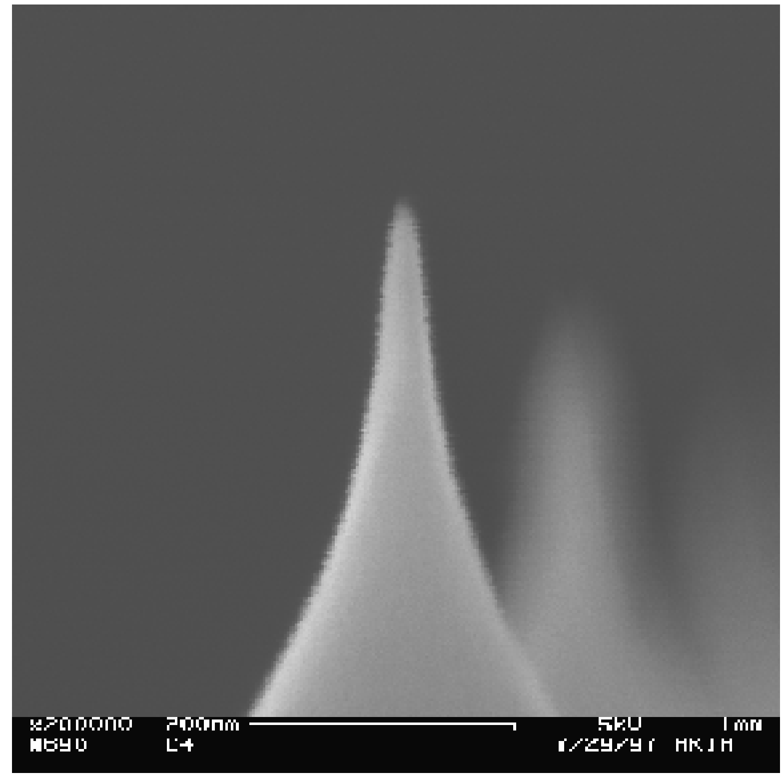




Si Field Emission Device

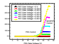
(1-μm gate aperture)

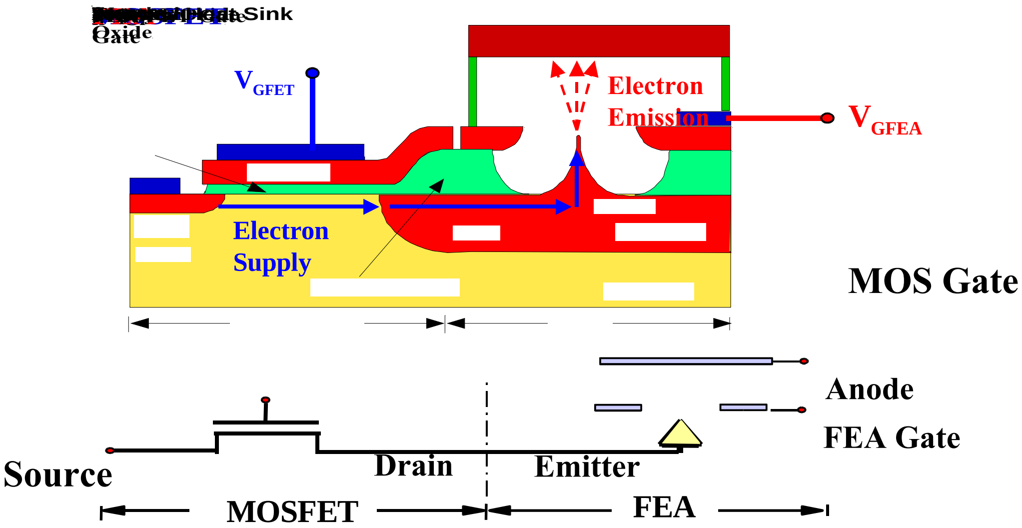


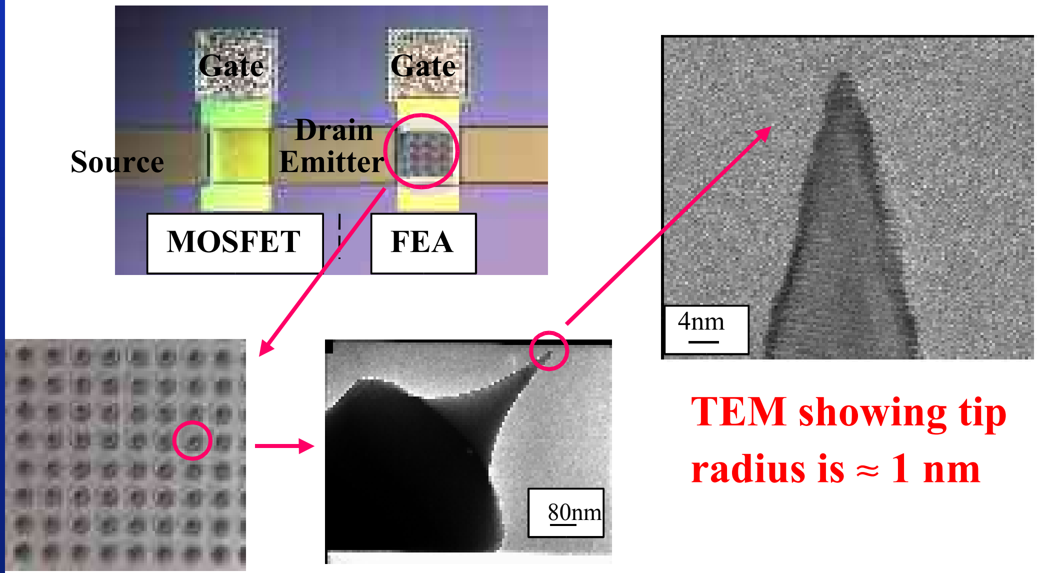


T. Akinwande

Smart Silicon MOSFET / Field Emission Devices (Akinwande)







TEM showing tip radius is ≈ 1 nm

Applications

- Field emission displays
- RF electron sources/amplifier
- Multi e- beam lithography

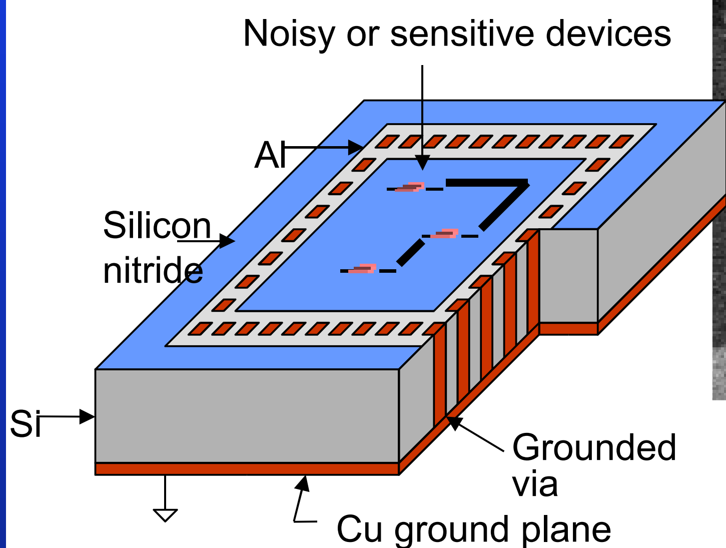
MOSFET control of electron emission results in

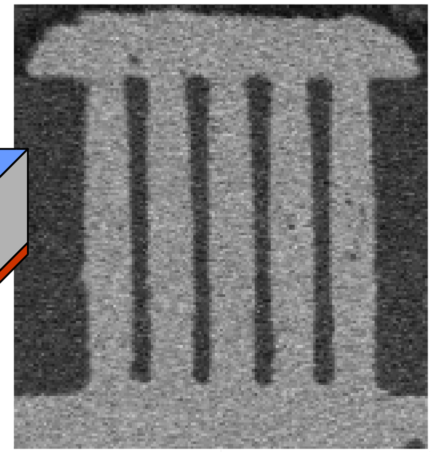
- low voltage control
- spatial uniformity
- temporal stability/ lower noise

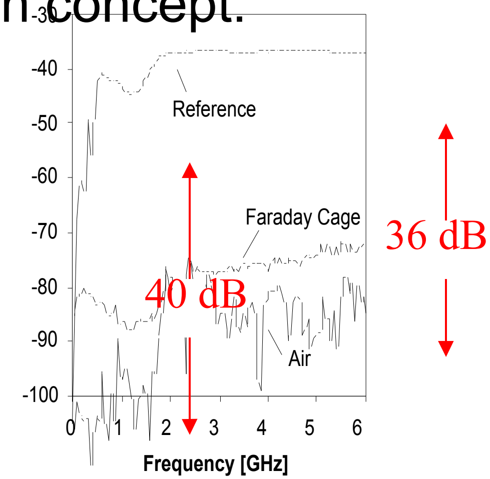
Sponsored by DARPA HDS Program

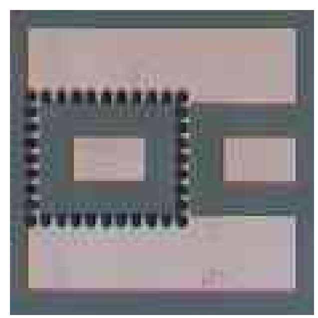
Integration of Function: Crosstalk Isolation for SoC Applications

New ***Faraday cage*** substrate crosstalk isolation concept:







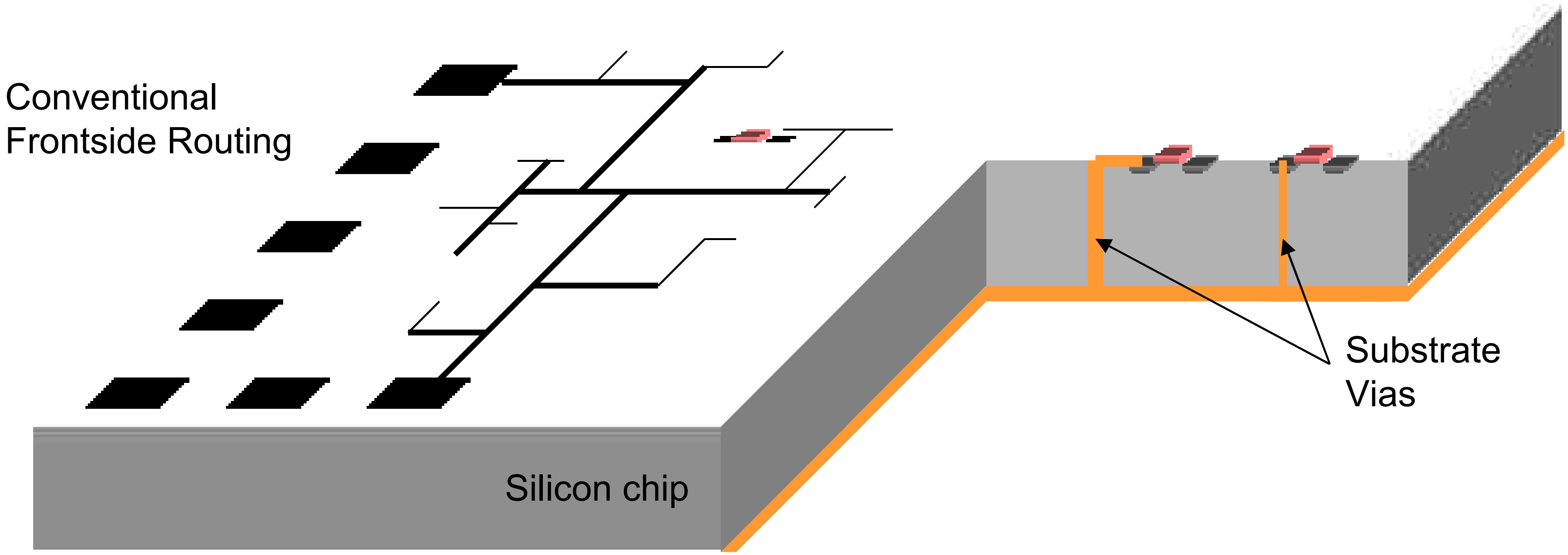


This project leverages MTL's MEMS technology onto Si RF world

World record crosstalk suppression at 1 GHz and 5 GHz (distance=100 μm)

J. delAlamo

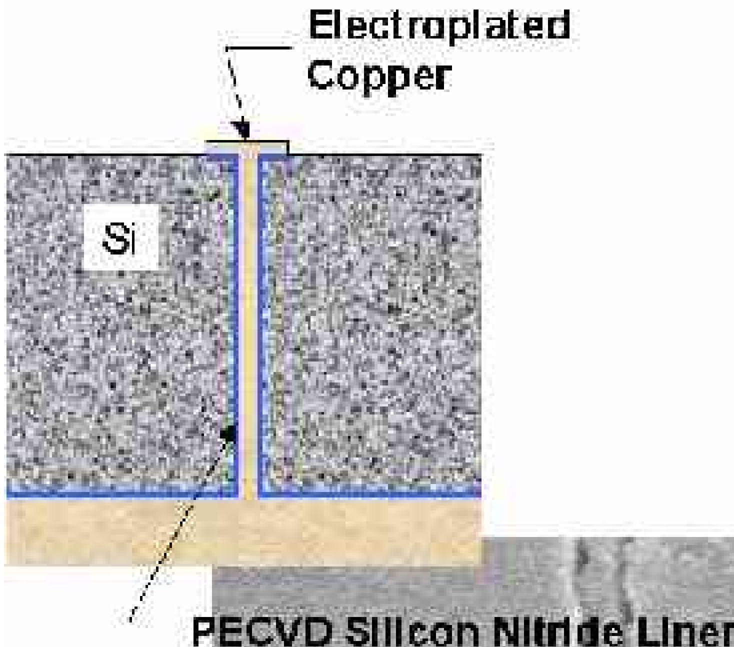
Silicon Substrate-Via Technology

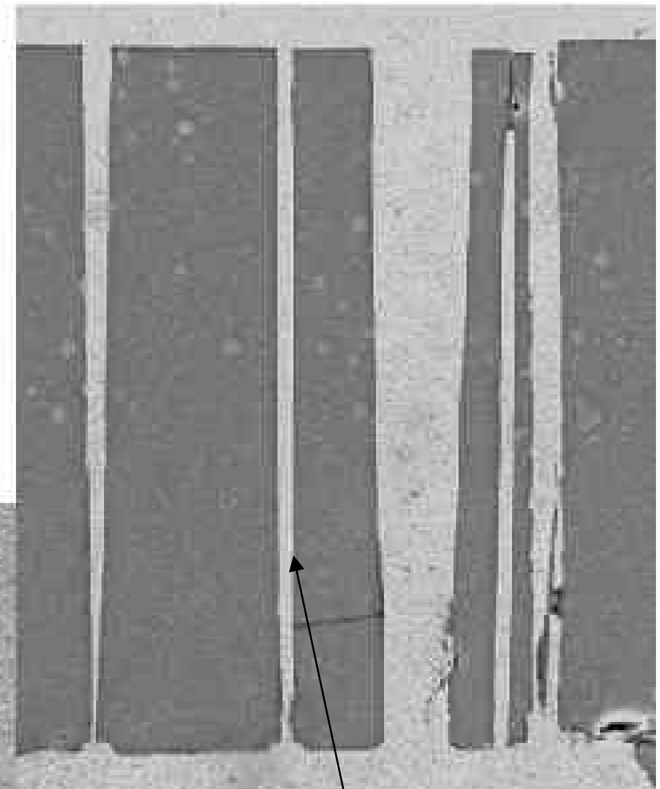


- Low-impedance ground for RF circuits
- Backside routing for power and ground in digital ICs
- Backside electrical connection for MEMS

J. Wu and J. A. del Alamo

Silicon Substrate-Via Technology



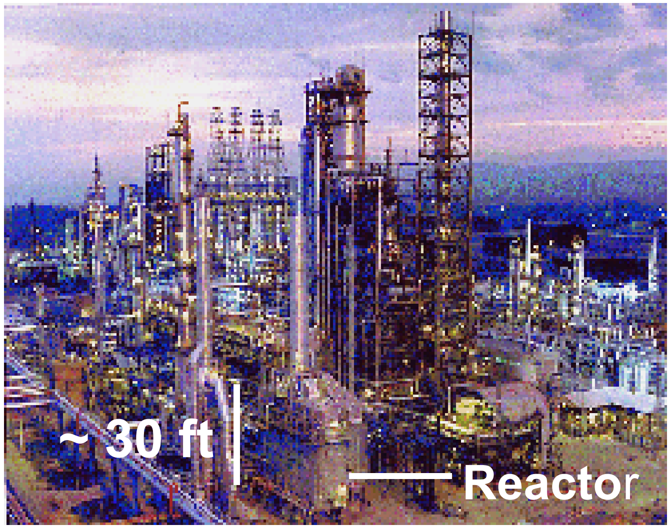


97 µm deep, 2 µm wide (49:1 aspect ratio)

Mid-via sidewall of 38 µm x 106 µm via

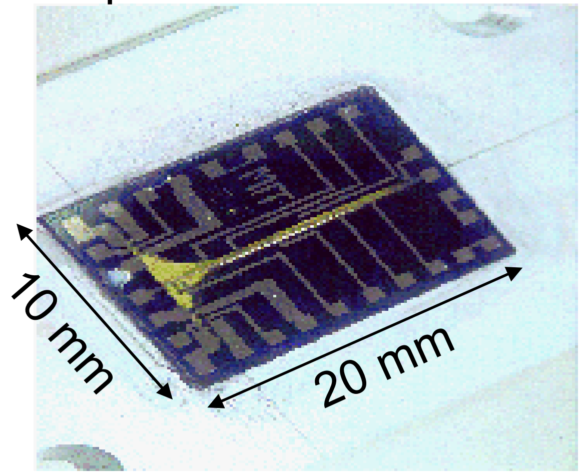
Microchemical Systems - Motivation

K.F. Jensen



❍ Can scale-up by replication of microfabricated reactors as opposed to

a few large units revolutionize chemical production?



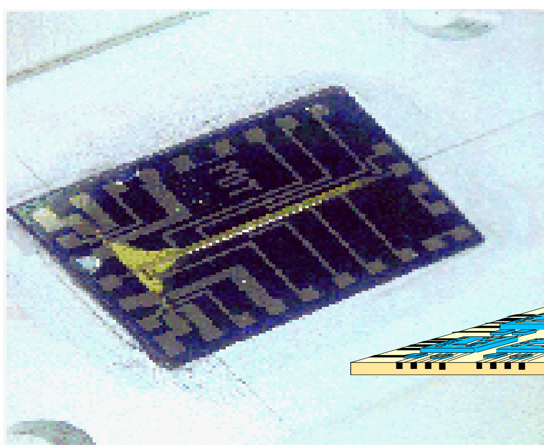
❍ Potential advantages:

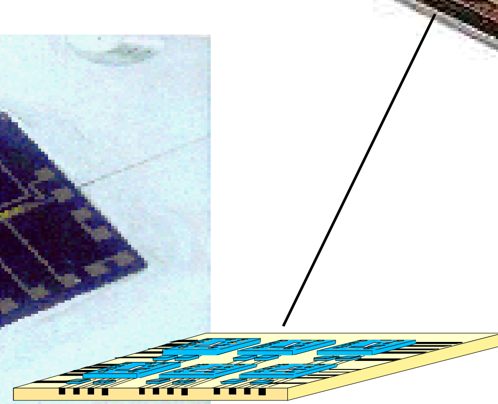
- Safer operation in small dimensions
- Improved chemical performance
- Distributed manufacturing - on demand production of toxic intermediates
- Fast scale-up to production by replication
- High throughput reaction/catalyst screening - combinatorial chemistry

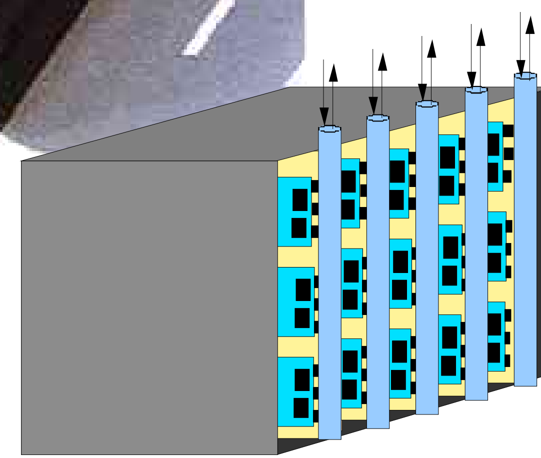
Integration into Arrays: Microchemical Systems

K.F. Jensen

- Scale-up of microreactor systems is by replication of the reactor unit
- Increased flexibility and faster laboratory-to-market transfer





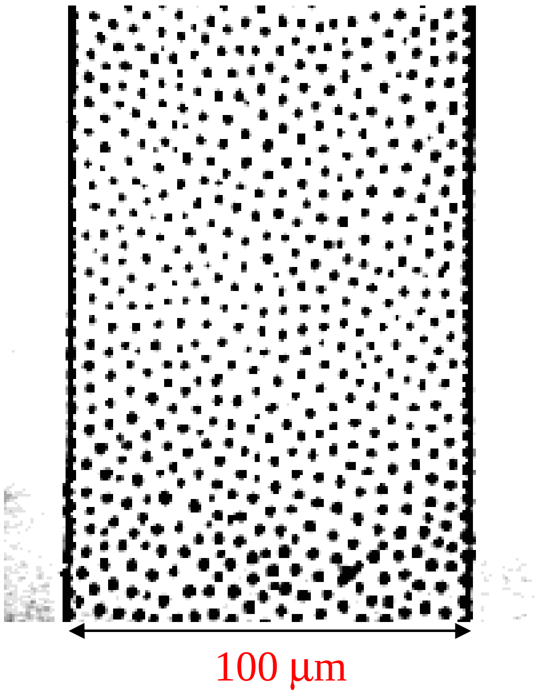


Chip Fluid Circuit Board Mini Chemical System

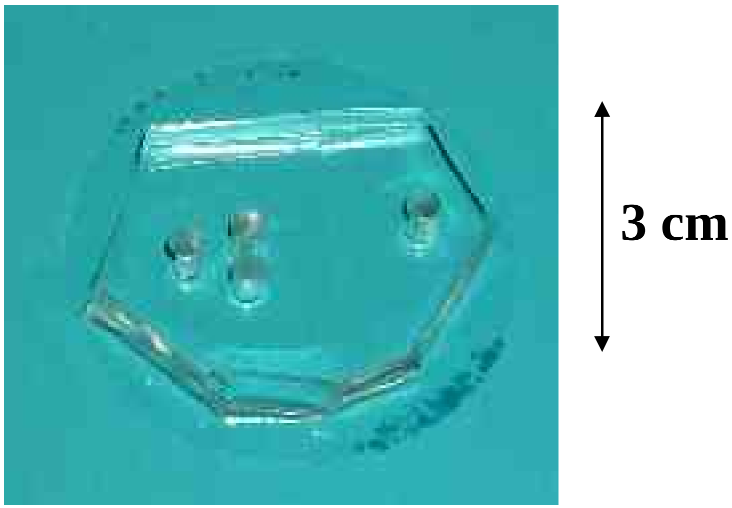
Experiments

P. Doyle

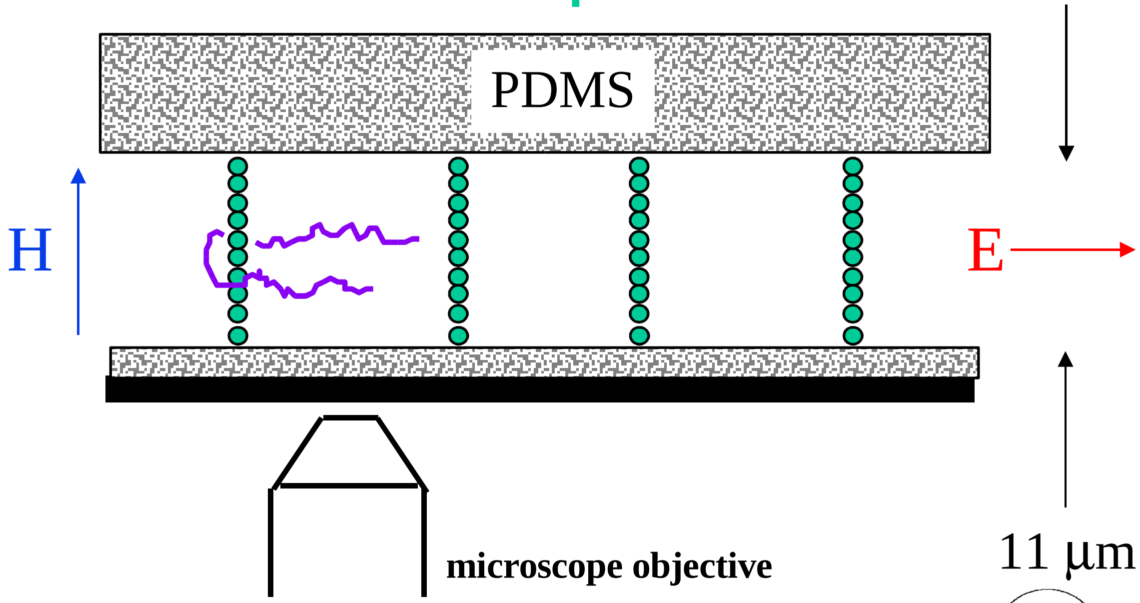
Separation Channel



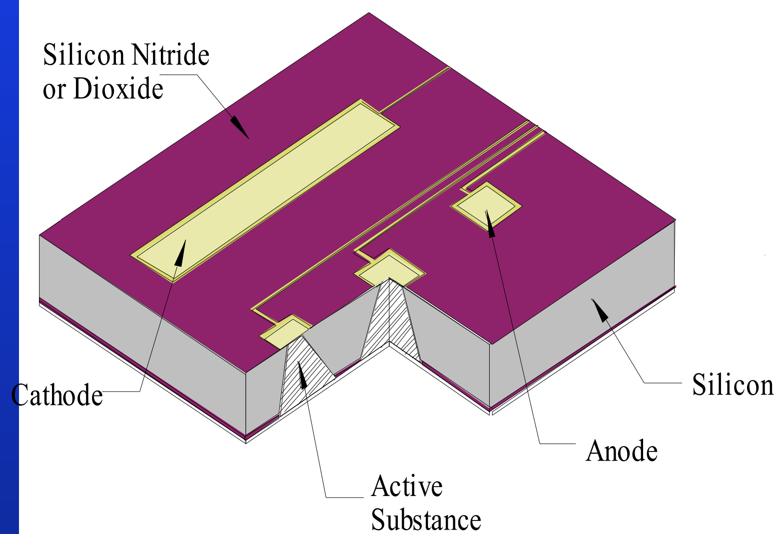
Elastomer Microchip

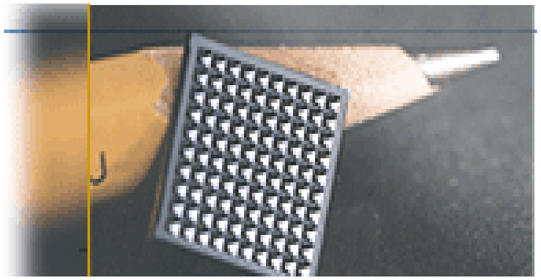


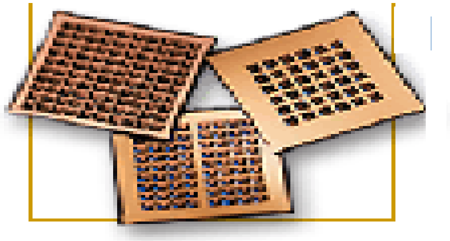
Schematic of Experiments



Drug Delivery



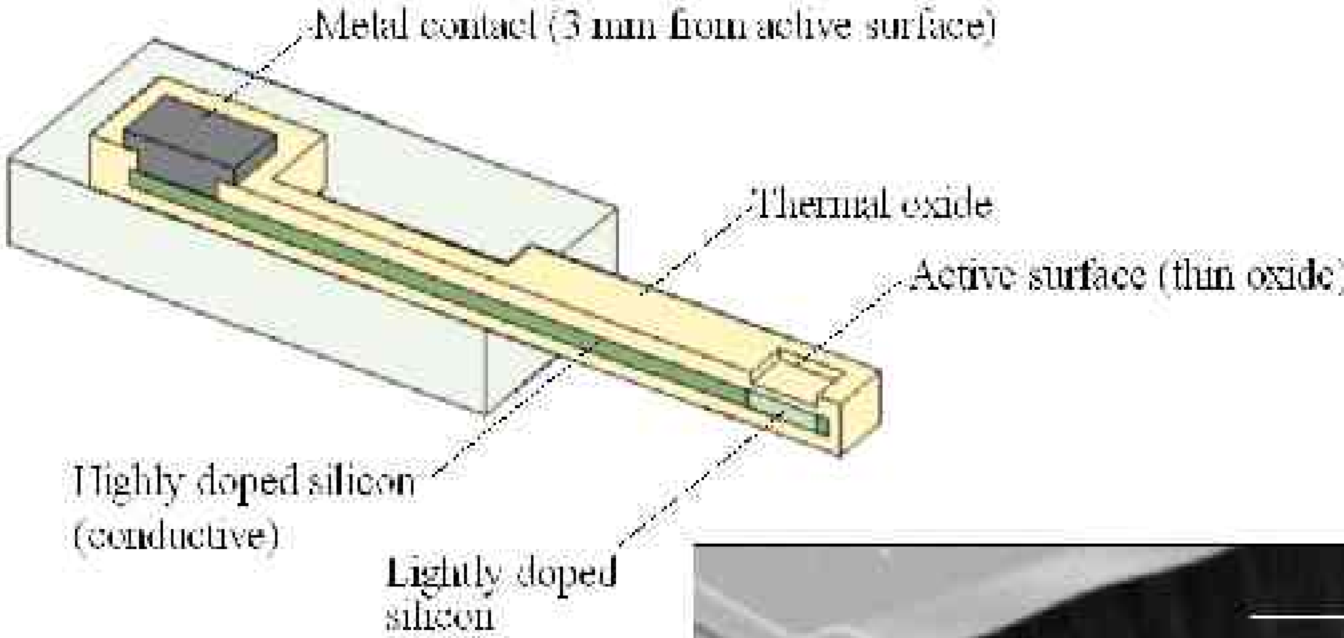


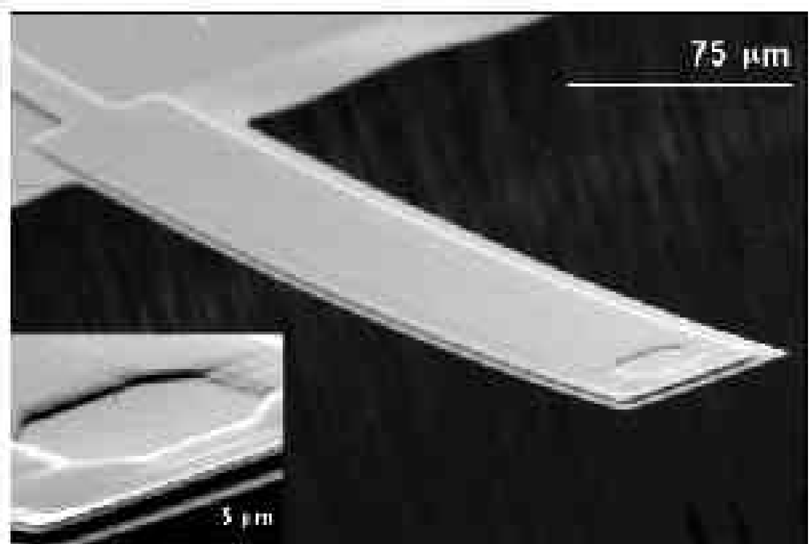


www.mchip.com

* Figure reprinted by permission from *Nature* 397, 335-338 (1999) Macmillan Magazines Ltd.

Silicon field-effect sensor for molecular biology



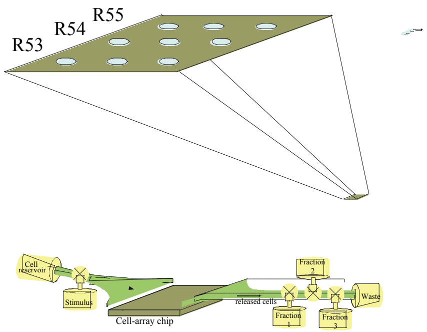


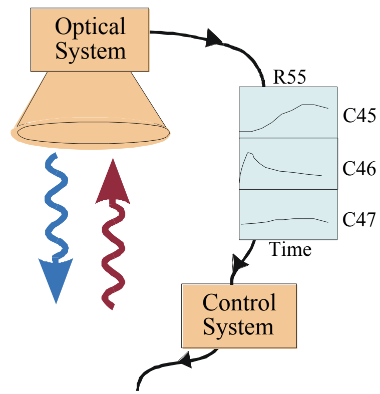
scanning electron micrograph

Manalis Group
MIT Media Laboratory

μDAC = microfabricated Dynamic Array Cytometer

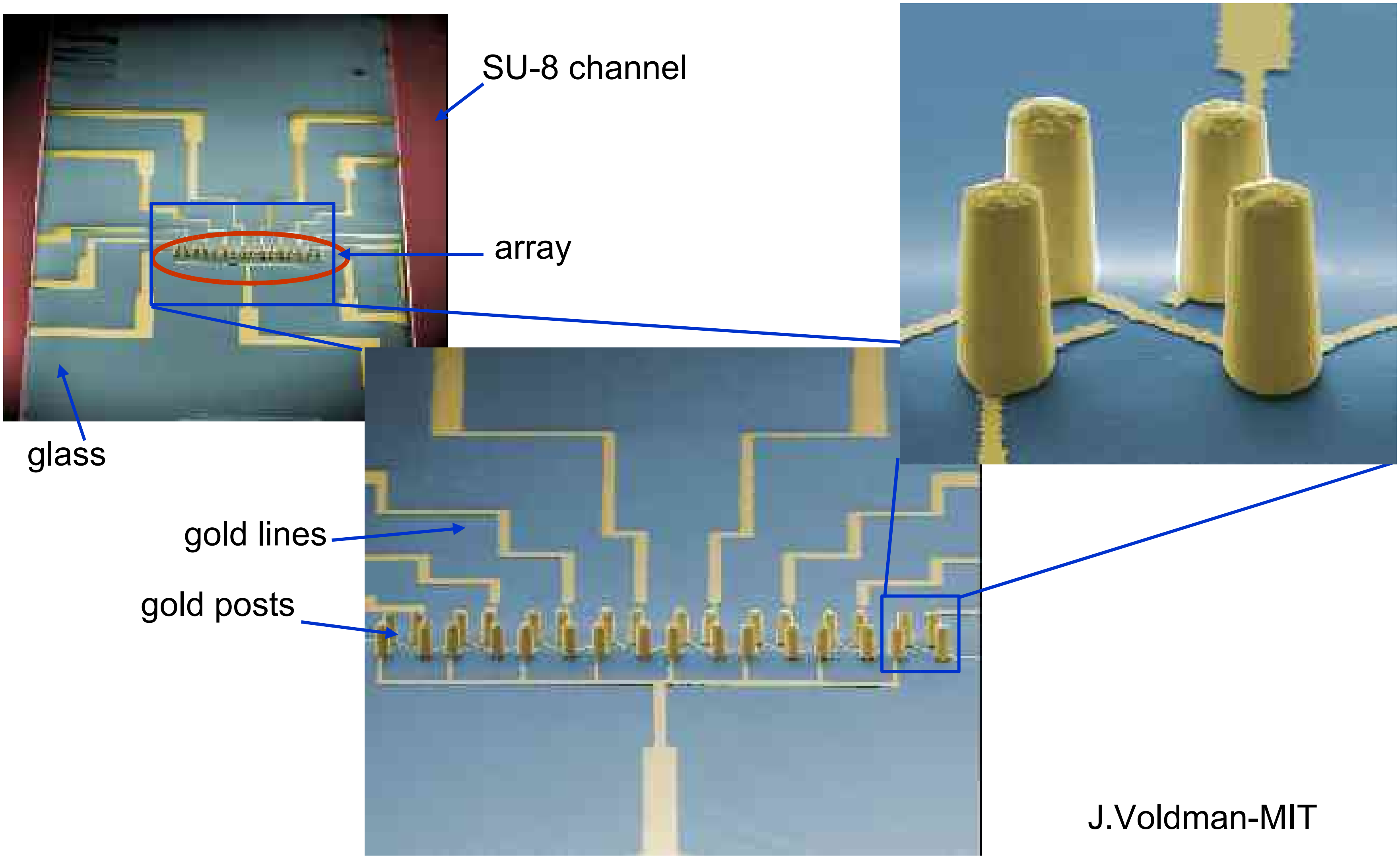
Monitors dynamics of many individual cells





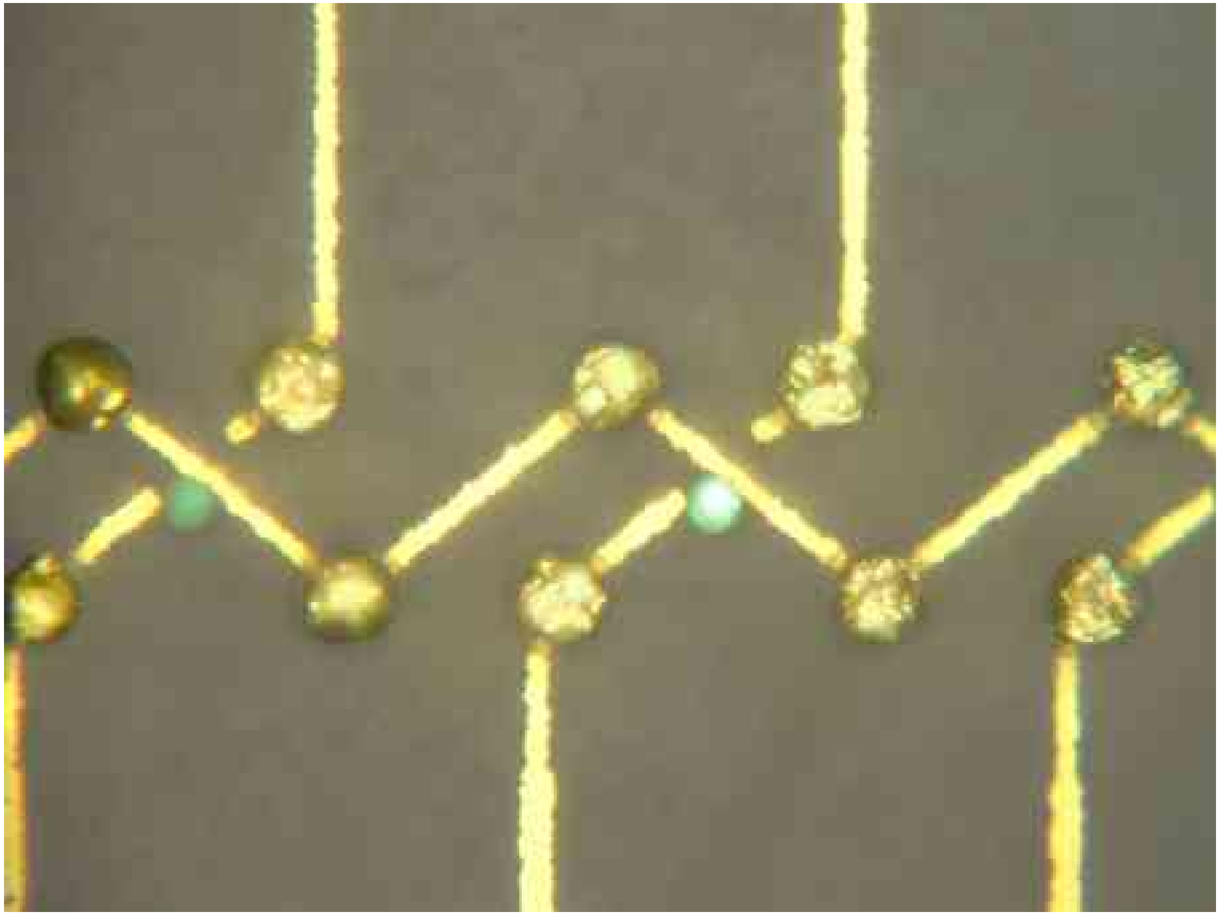
Courtesy: J.Voldman-MIT

Final structure



J.Voldman-MIT

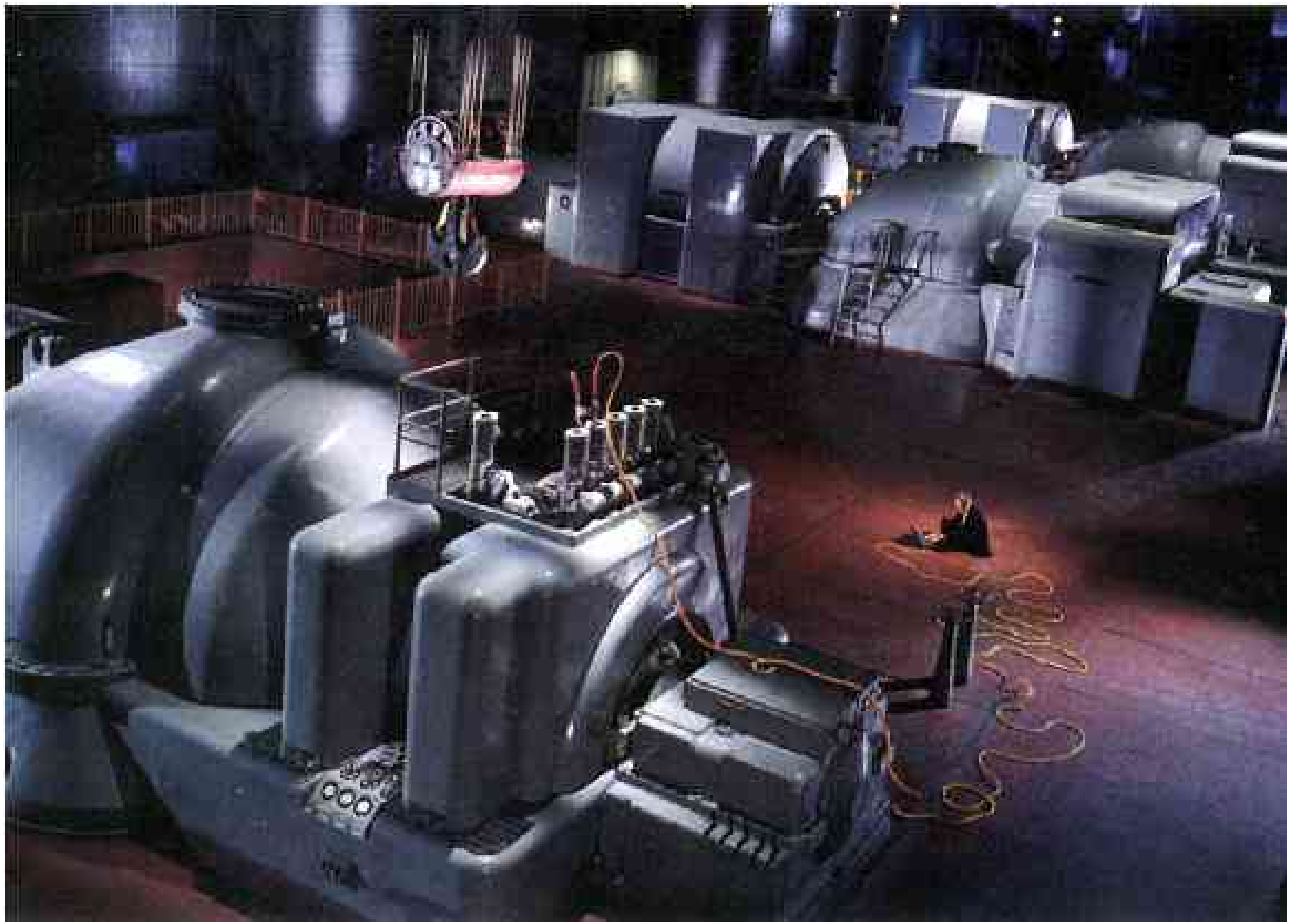
Manipulating cells



Calcein-labeled HL-60 cells

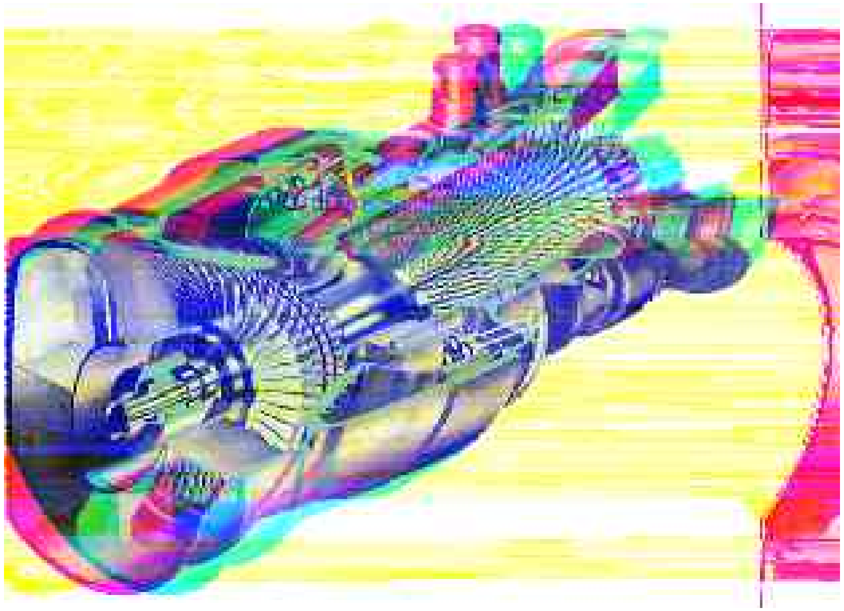
J.Voldman-MIT

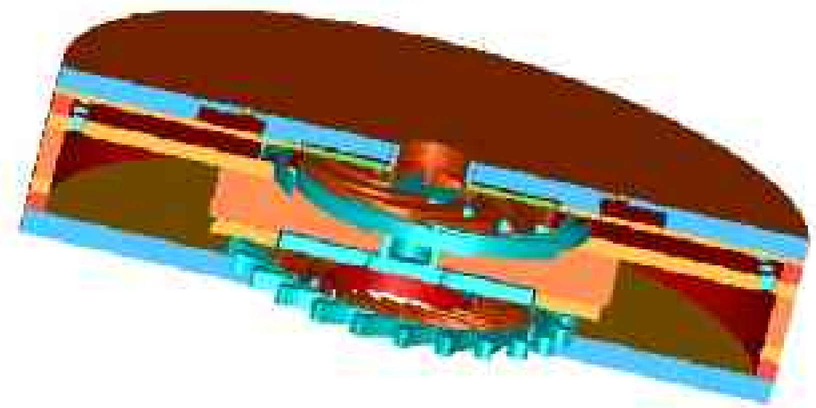
Electric Power: Current Technology



A. Epstein

MIT Micro Gas Turbine Generator





	Micro Turbo Generator	LiSO2 Battery (BA5590)
Power Output	50 W	50 W
Weight	50 grams	1000 grams
Specific Energy	3500 W-hr/kg	175 W-hr/kg

– A portable power source with ten times the power density of state-of-art batteries

Demo Engines

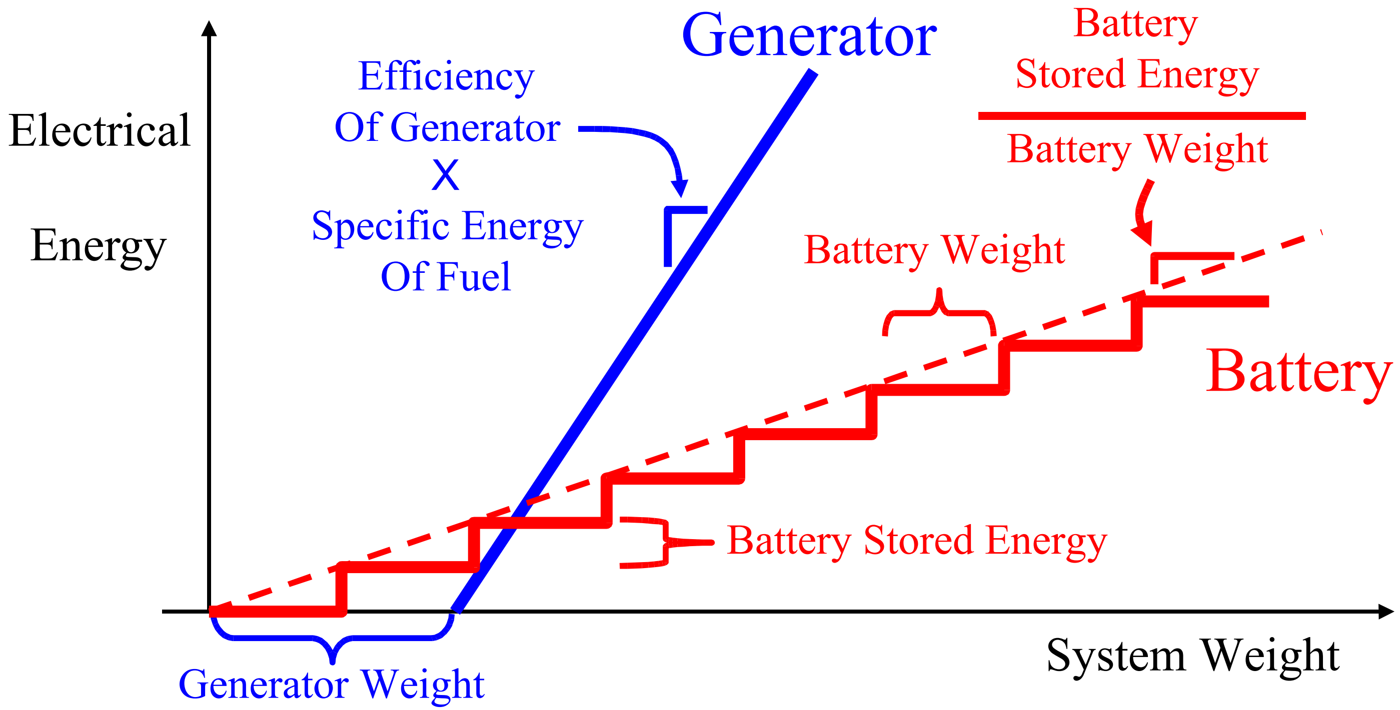
Batteries vs. Fuel

- Batteries
  - ~500 Watt-hours per kilogram for Primary Systems
  - ~120 W-h/kg for Secondary (Rechargeable) Systems
- Fuel Combustion
  - ~39,000 W-h/kg for Hydrogen
  - ~14,000 W-h/kg for Propane or Butane (C_3H_8 / C_4H_{10})
  - ~12,000 W-h/kg for Gasoline
  - ~6,000 W-h/kg for Methanol

Fuel Contains 10-300x the Specific Energy of Batteries

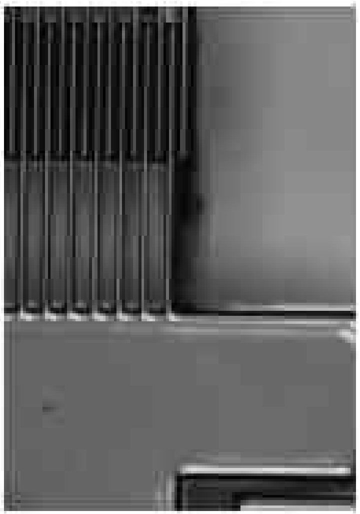
Courtesy: S.Schaevitz

Advantages of Fuel Burning

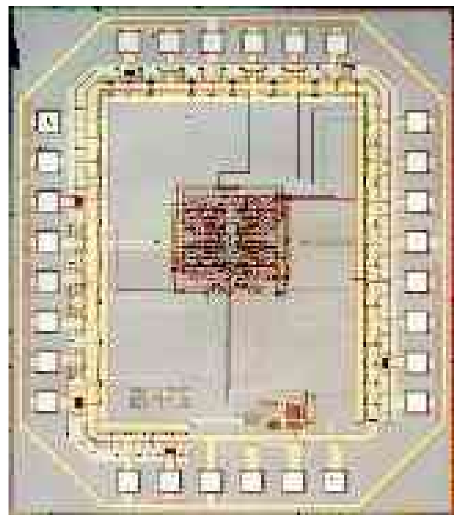


Courtesy of S. Schaevitz

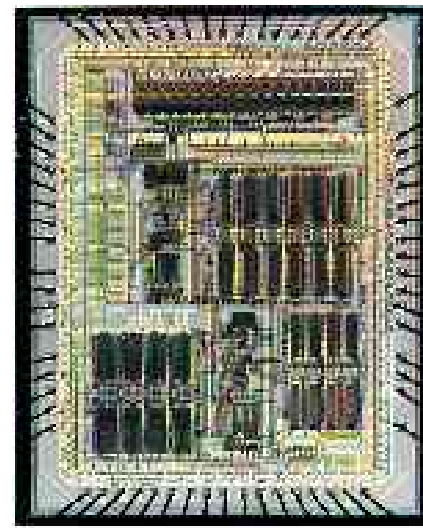
Energy Scavenging



Jose Mur Miranda



Scott Meninger



Rajeevan Amirtharajah

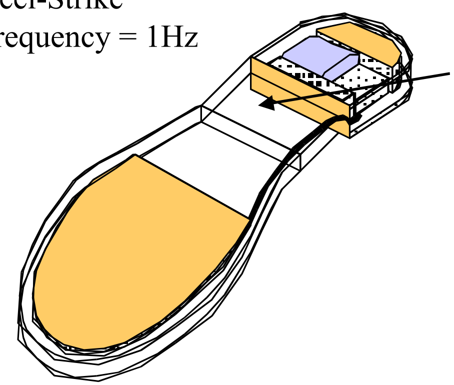
A. Chandrakasan, J. Lang

- Energy can be scavenged from mechanical vibrations to power micropower sensor systems

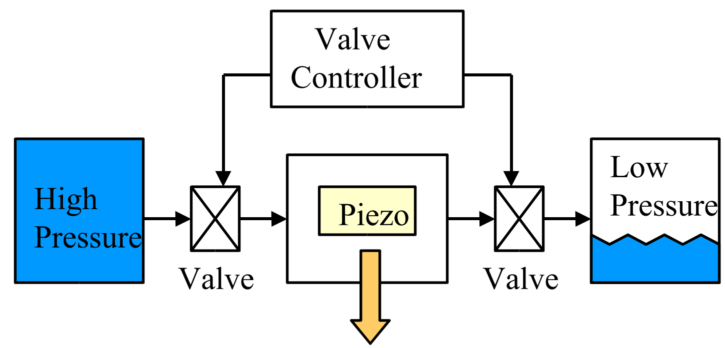
Heel-Strike Energy Harvesting

Heel-Strike
Frequency = 1Hz

Device Size:
~ 1cm x 3cm x 3cm

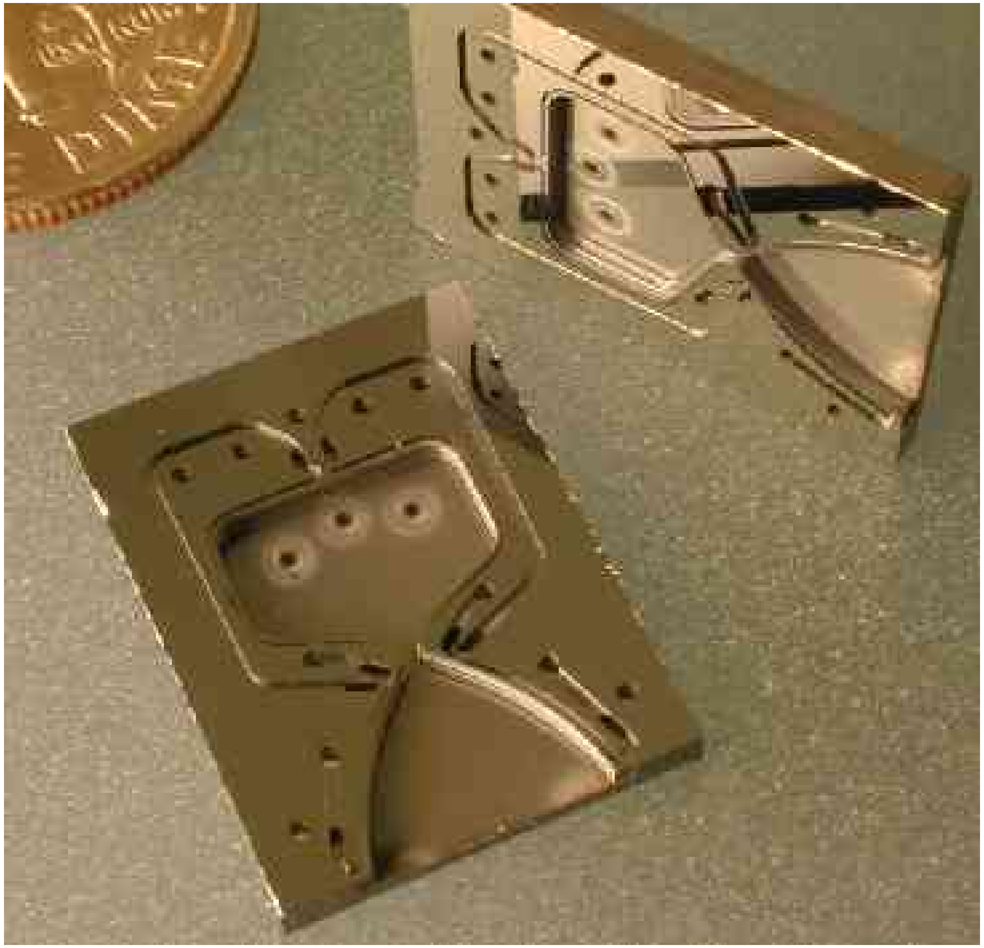


Valve Operating
Frequency ~ 30 kHz

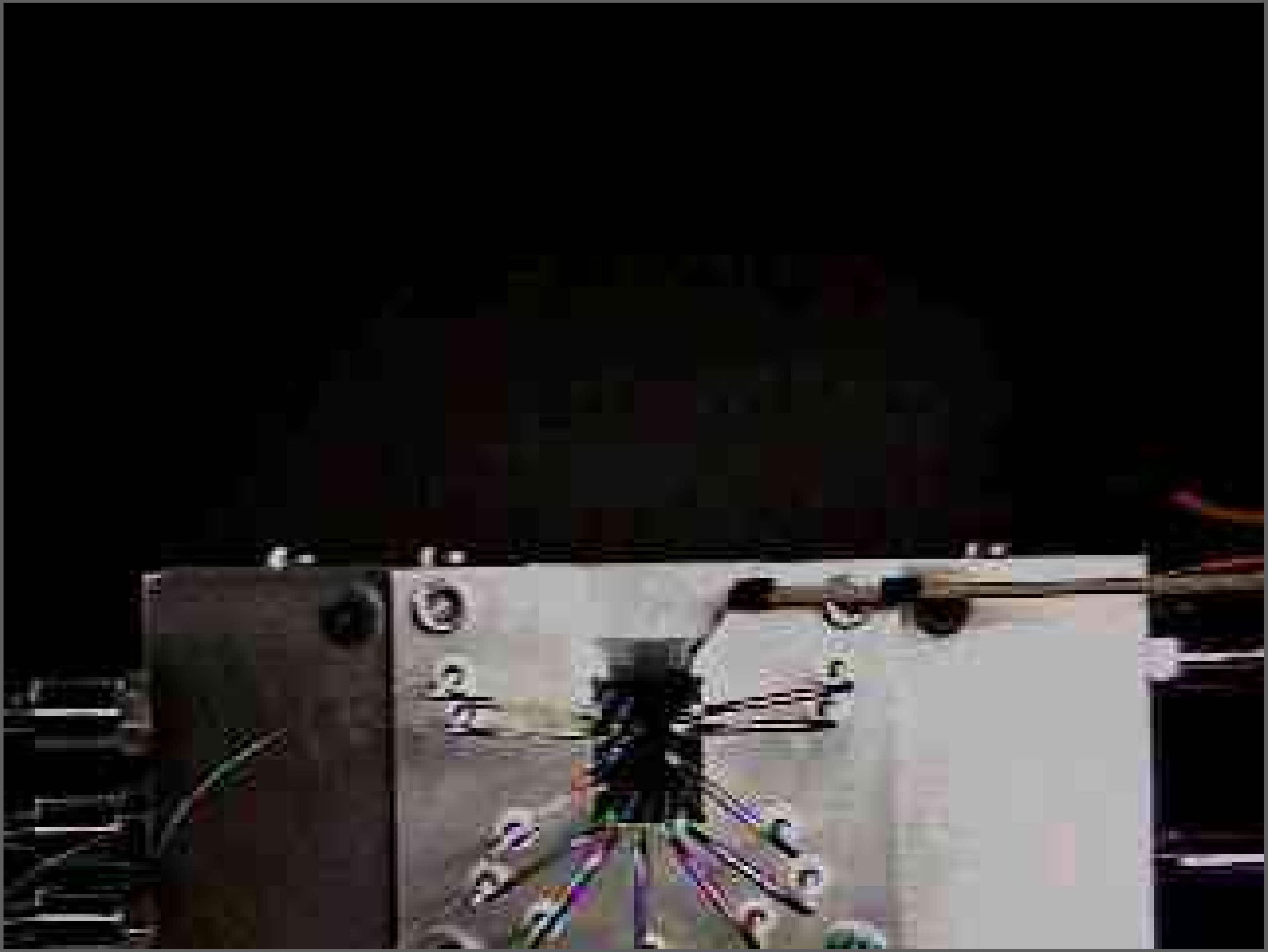


Objective: To develop a heel-strike energy harvesting device (~0.5-1 W) that generates electrical energy from the low frequency stepping motions of a foot soldier.

Microrocket Engine



The rocket's first firing….



What does it take?

- An Incubator, that:
  - Enables people to cross disciplinary boundaries
  - Encourages free flow of information across projects at the 'core technology' level
- The MTL (*Technology Infrastructure – System Focus*)
  - ~350 researchers (3% of MIT student population)
  - Shared experimental facilities
    - Cleanrooms, Testing, CAD, IC Design
  - Participants from 29 Departments/Labs/Centers
- The Output:
  - *Ideas*
  - *Students*