

MEMS @ MIT Overview

Prof. Martin A. Schmidt
Fall 2007

www.mtl.mit.edu/mems

MEMS @ MIT 'At a Glance'

- Community
 - ~30 Faculty
 - ~135 Students and staff
 - ~\$15M Annual Sponsorship (Federal and Industrial)
- Major Thrusts
 - Materials, Processes, and Devices for MEMS
 - Biological and Chemical MEMS
 - Actuators and Power MEMS
 - Sensors, Systems, and Modeling
- Established as an 'internal' community in 2000
- Launched industrial membership in 2006

MEMS @ MIT Faculty

- A.I. Akinwande (EECS)
- G. Barbastathis (MechE)
- M. Bazant (Math)
- S. Bhatia (HST/EECS)
- D. Boning (EECS)
- A. Chandrakasan (EECS)
- G. Chen (MechE)
- M. Culpepper (MechE)
- P. Doyle (ChemE)
- A. Epstein (Aero/Astro)
- D. Freeman (EECS)
- M. Gray (HST/EECS)
- J. Han (BioEng/EECS)
- K. Jensen (ChemE/MatSci)
- R. Kamm (MechE)
- R. Karnik (MechE)
- S.G. Kim (MechE)
- J.H. Lang (EECS)
- C. Livermore (MechE)
- S. Manalis (BioEng/MechE)
- D.J. Perreault (EECS)
- M.A. Schmidt (EECS)
- A. Slocum (MechE)
- C.V. Thompson (MatSci)
- T. Thorsen (MechE)
- J. Voldman (EECS)
- E. Wang (MechE)
- B. Wardle (Aero/Astro)
- J. White (EECS)
- F. Yanik (EECS)



MEMS@MIT Industrial Consortium



MEMS @ MIT Industrial 'Value Proposition'

- Provide early insight to research activities and results
- Provide preferred access to MIT personnel engaged in MEMS research
- Create a gateway to collaborative research partnerships
 - Funded by industry, government, or foundations
 - Providing specific IP benefits
- Establish a forum for exchange of ideas on new areas and technology/industry trends
- Facilitate technology transfer
 - Visits
 - IP Briefings
 - Reports, Theses
- Provide an exclusive portal for MEMS information
 - Streaming seminars
 - Publications



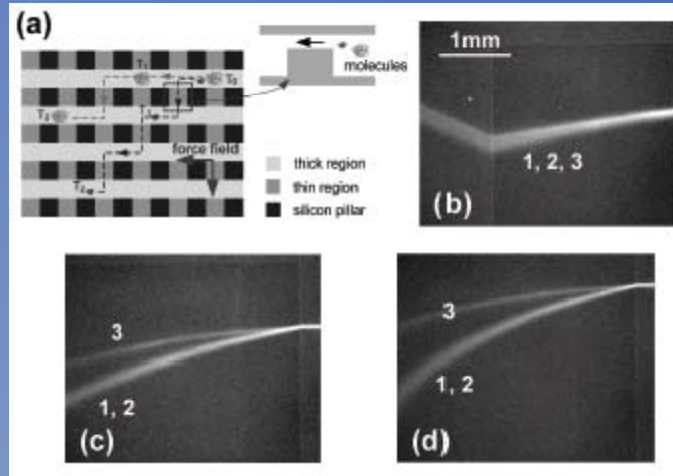
Research Overview

Major Research Themes

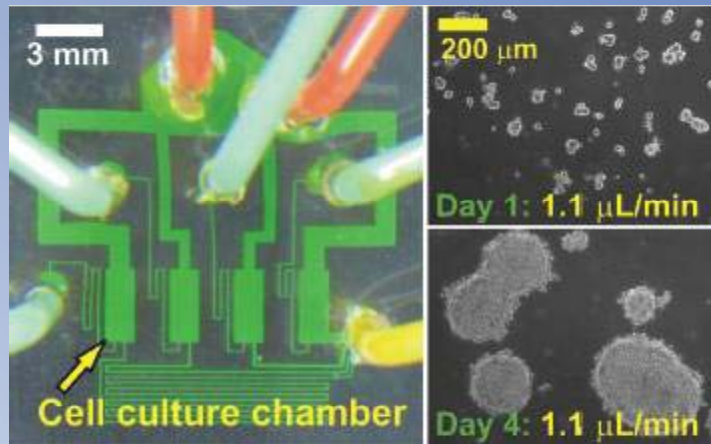
- Materials, Processes, and Devices for MEMS
 - Piezoelectrics, Magnetics, Materials/Package Reliability, DRIE, Wafer Bonding, Plastic Fab, Printed MEMS
- Biological and Chemical MEMS
 - Cell Manipulation, DNA and Protein Processing, Biomolecule Detection, Medical Sensors, Microreactors, Micro Gas Analyzers, Microfluidics
- Actuators and Power MEMS
 - Switches, Mirrors, Pumps, Turbines, Fuel Cells, Thermophotovoltaics, Chemical Lasers, Energy Harvesting
- Sensors, Systems, and Modeling
 - Wireless Sensors, Pressure Sensing Systems, MEMCAD

Biology

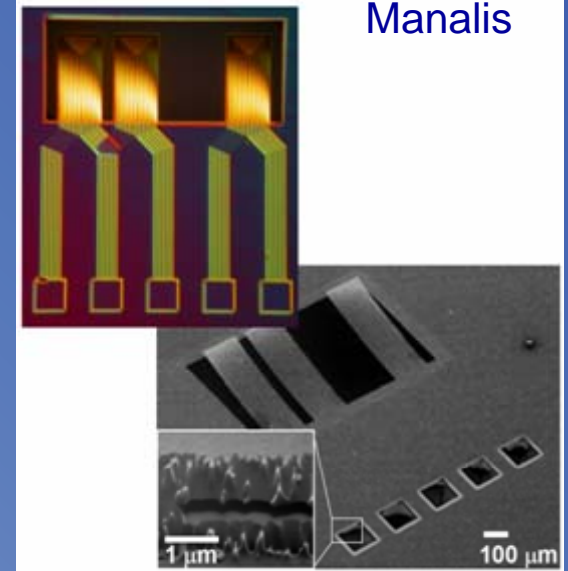
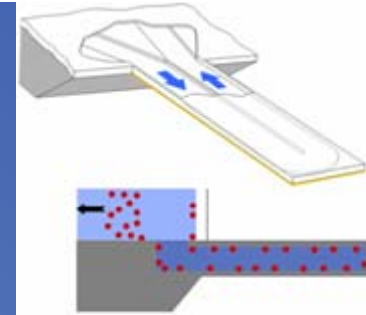
- Tissue Engineering
- Fermentation
- Cell Manipulation
- DNA Sorting
- Protein Detection



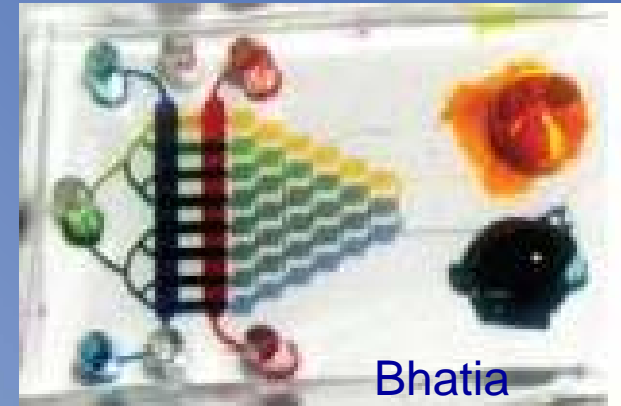
Han



Voldman



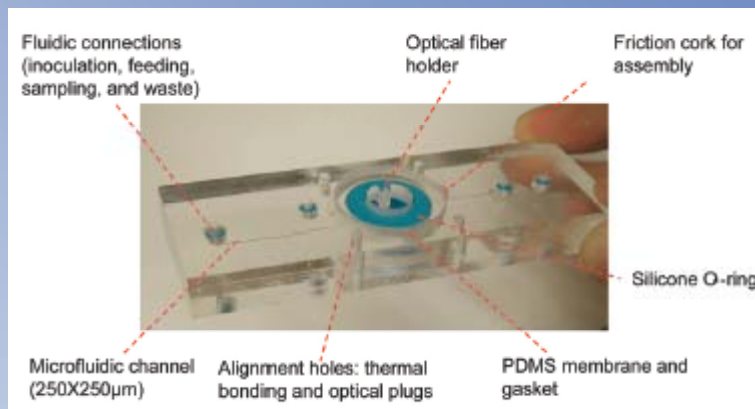
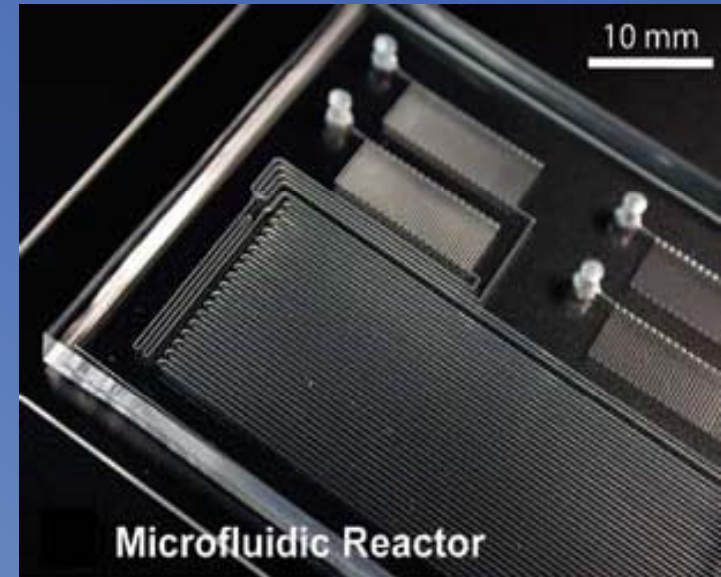
Manalis



Bhatia

Chemical/Microfluidics

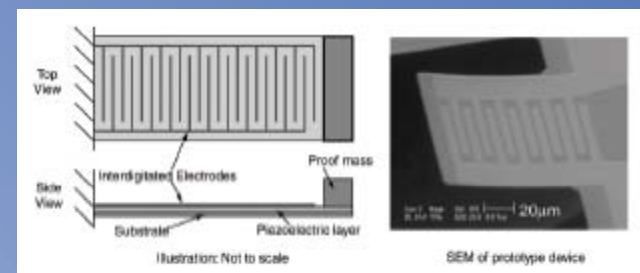
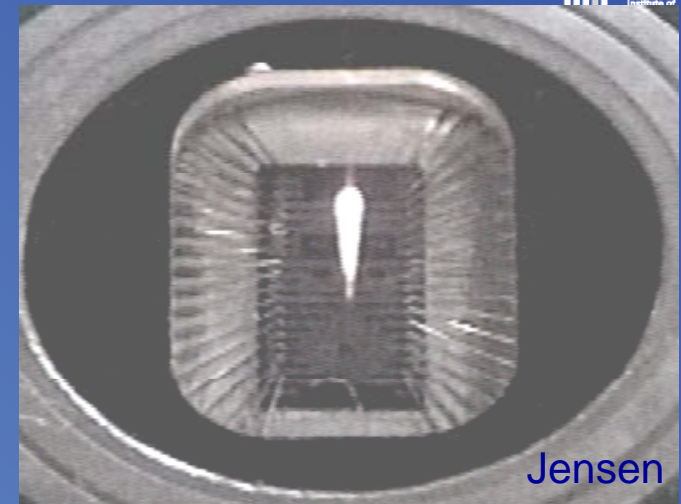
- Synthesis
 - Microreactors for Quantum Dots
- Screening
 - Catalysts
 - Pharma
- Lab-on-a-Chip
 - Detection
- Large Array Processors



Jensen

Power MEMS

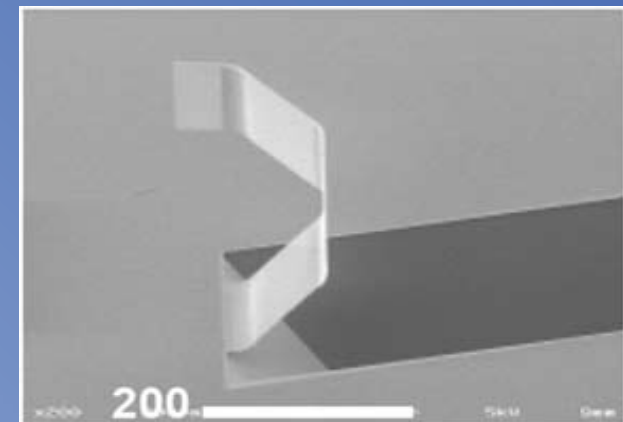
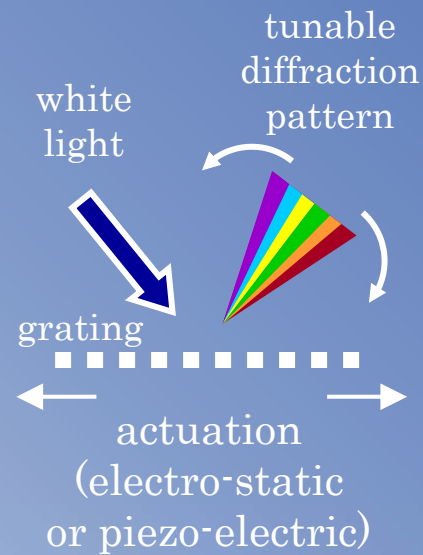
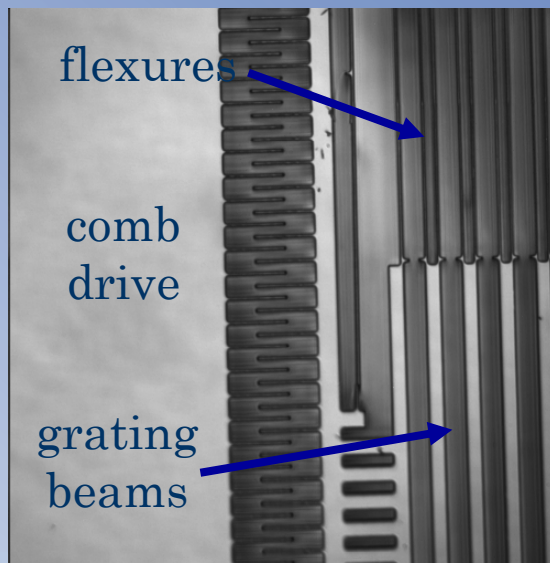
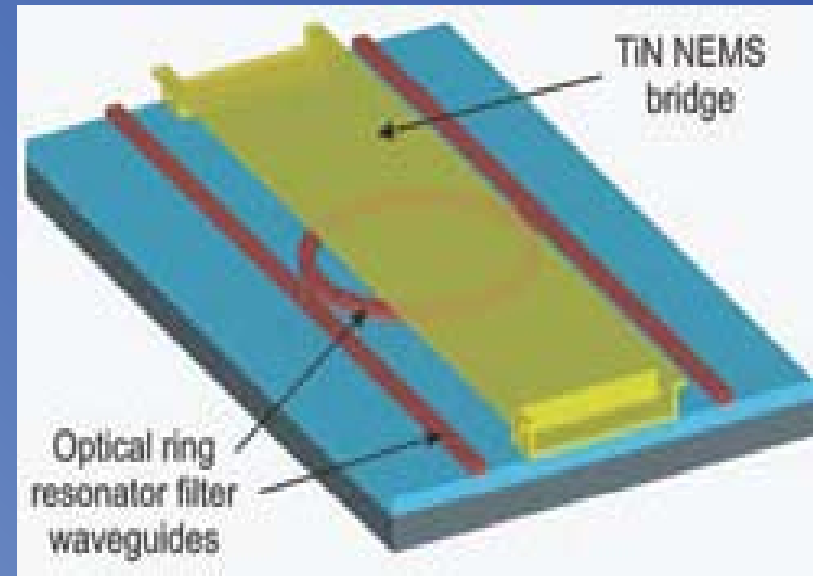
- Energy Scavenging
 - Vibration
 - Heel-Strike
- Fuel Processing
 - ThermoPhotoVoltaic
 - ThermoElectric
 - MicroFuel Cells
 - MicroTurbines
- Rockets



Kim/Wardle

Optical

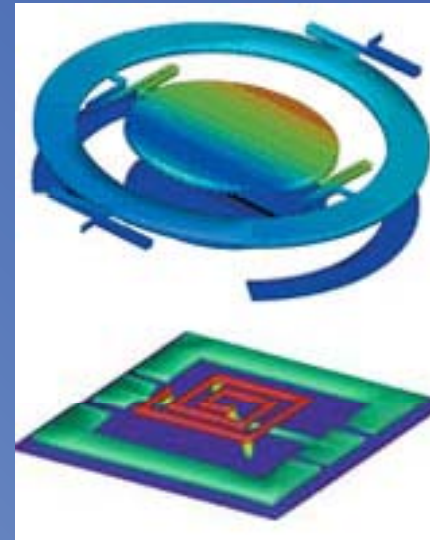
- Tunable Filters/Gratings/Resonators
- Mirrors
- Optical Sensors



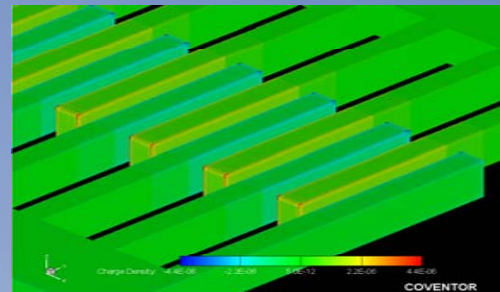
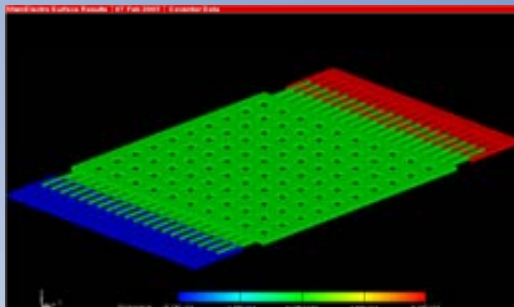
Kim/Barbastathis

CAD/Modeling

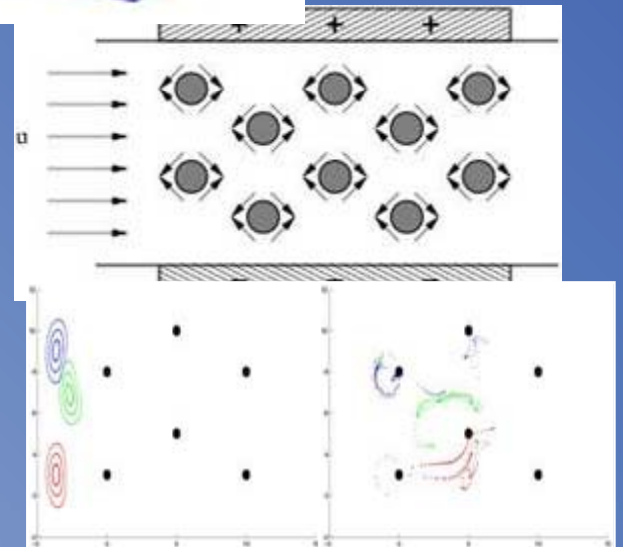
- MEMCAD
 - Computationally-Efficient Algorithms
 - Coupled Simulations
 - Electro-Fluid-Mechanical
 - Magnetic
 - Macromodels
- ElectroHydrodynamics



White/Daniel

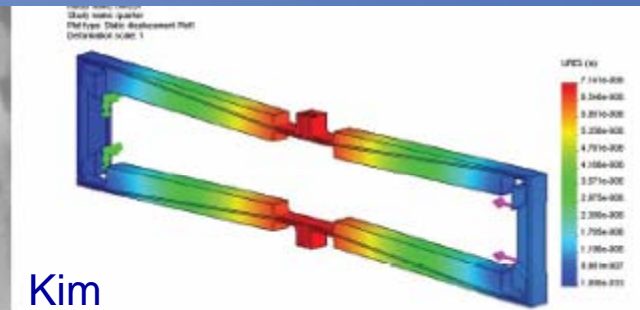
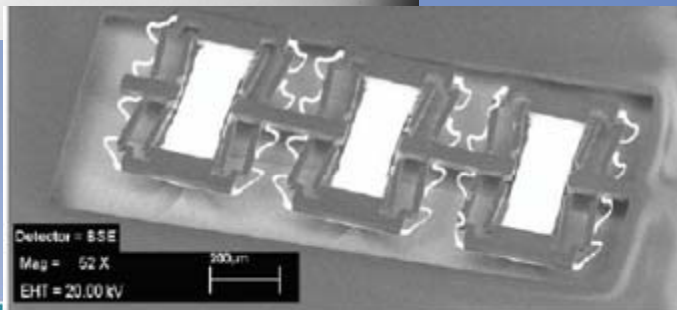
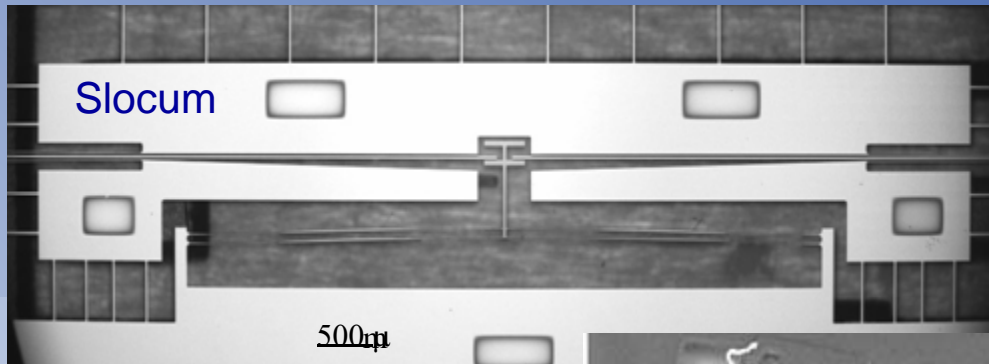
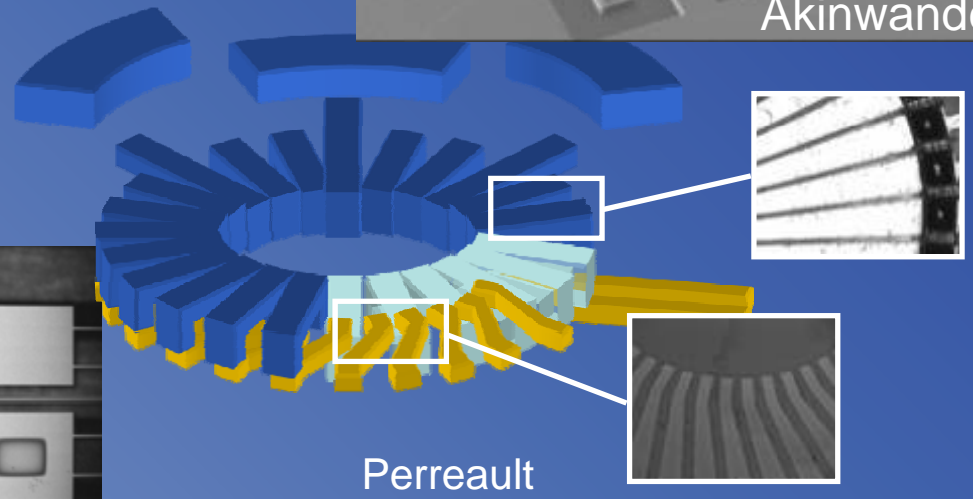
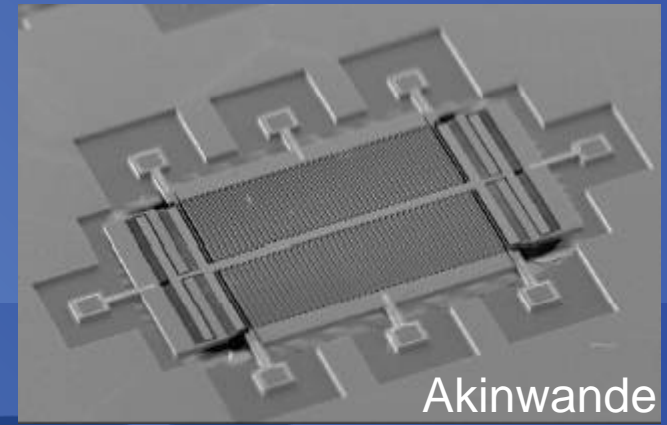
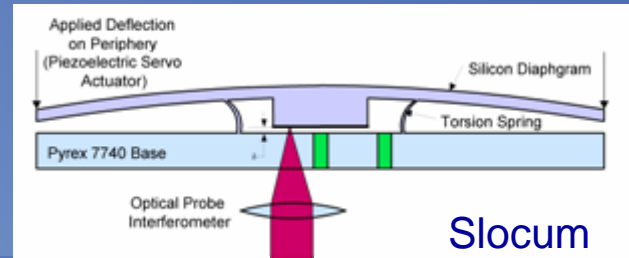


White/Daniel

Bazant
12

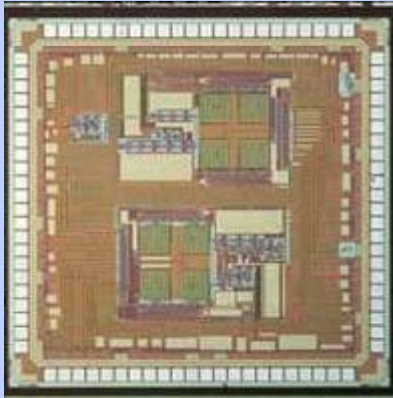
Devices

- Sensors
- Actuators
 - Switches
- Valves
- Power Components
- RF MEMS
 - Tunable Capacitors



Chipset for Wireless Sensor Networks (Chandrakasan)

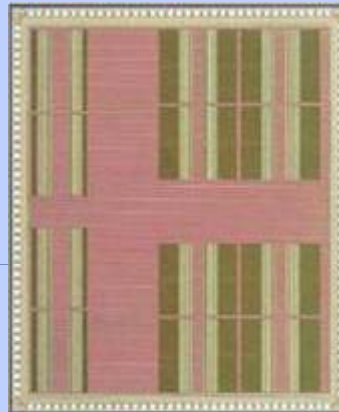
ADC



SAR ADC

- Scalable rate (0-100KS/s) and precision (12b & 8b)
- **25 μ W at 100kS/s**

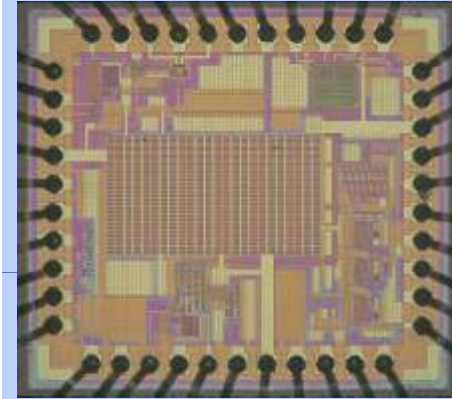
DSP



Sensor DSP

- 16-bit programmable DSP with FFT (128-1024 points)
- **100 μ W at 0.5V**

RF

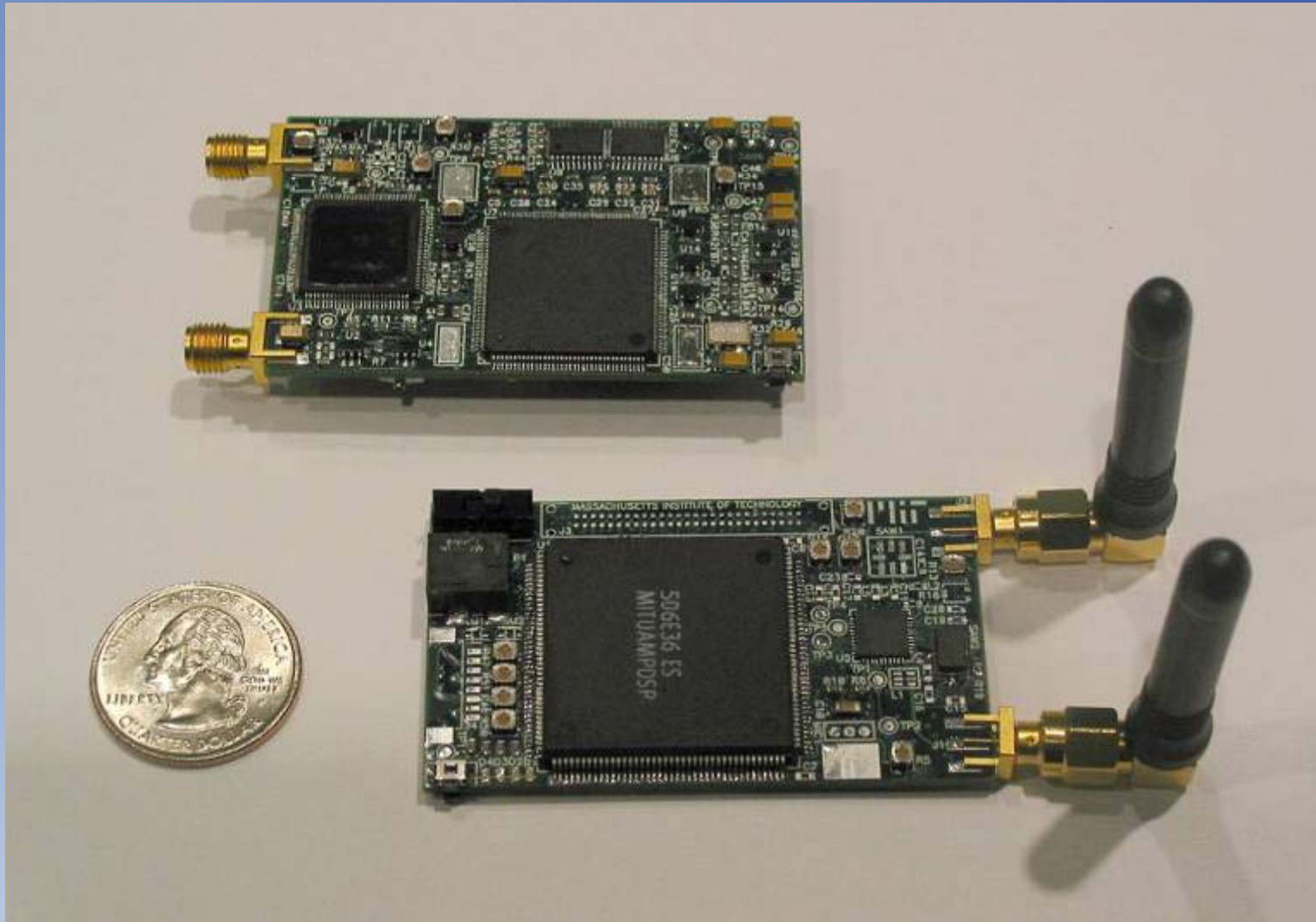


Low-Rate RF

- On-Off Keying using a rectification based receiver
- **Rx Energy: 1-3 nJ/bit**

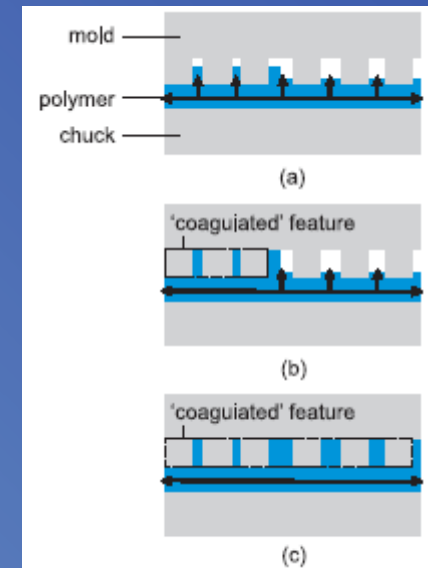
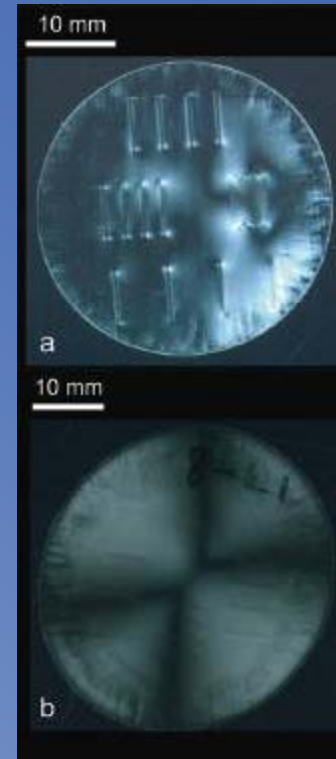
N. Verma (ADC), D. Finchelstein and N. Ickes (DSP), D. Daly (RF)

Integrated Node (Chandrakasan)

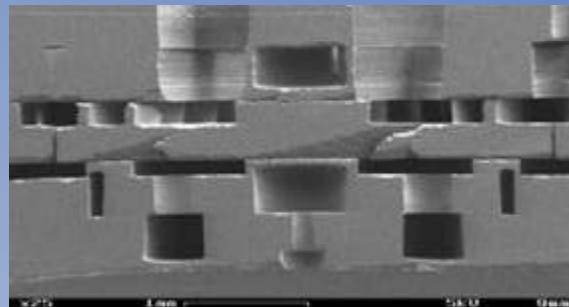
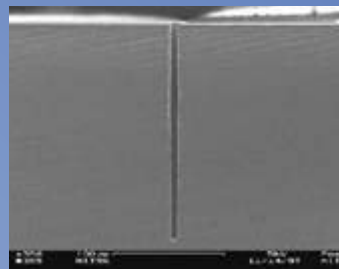


Technology

- DRIE
 - Thru-wafer Interconnect
- Wafer Bonding
- Plastic Fab
- Piezoelectrics
- High T Materials
 - SiC
- Thin Film Stress
- MEMCAD
- Packaging



Boning



Livermore


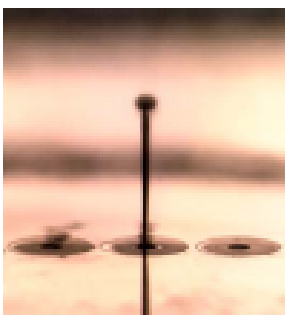



New Initiatives

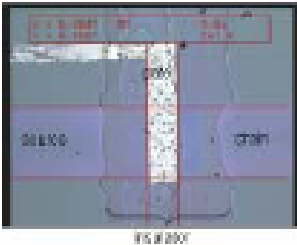
- Center on Non-lithographic Fabrication of MEMS/NEMS
 - \$1.75M/year effort involving MIT, Oregon State, and HP
 - Leverage HP printing technology into large area, low cost, rapid MEMS fabrication
- Hybrid Insect MEMS (HIMS)
 - Collaboration of MIT, University of Arizona, and University of Washington
 - Hybrid integration of MEMS with insects for autonomous flight
 - Drives research in energy harvesting, low power devices (circuits, MEMS)

Focus Center on Non-Lithographic Technologies for MEMS/NEMS: Summary

Mission: The development of revolutionary ways to fabricate MEMS and NEMS without the need for planar lithography and IC technology, leveraging the world leading expertise of HP (printing), MIT (MEMS) and OSU (printed electronics), to deliver a technology base for discovery and exploration of novel MEMS/NEMS.

Materials and Methods to

Devices and Systems



Impact:

- MEMS/NEMS on any surface
- Rapid prototyping
- Extremely low cost (/area)
- Heterogeneous integration

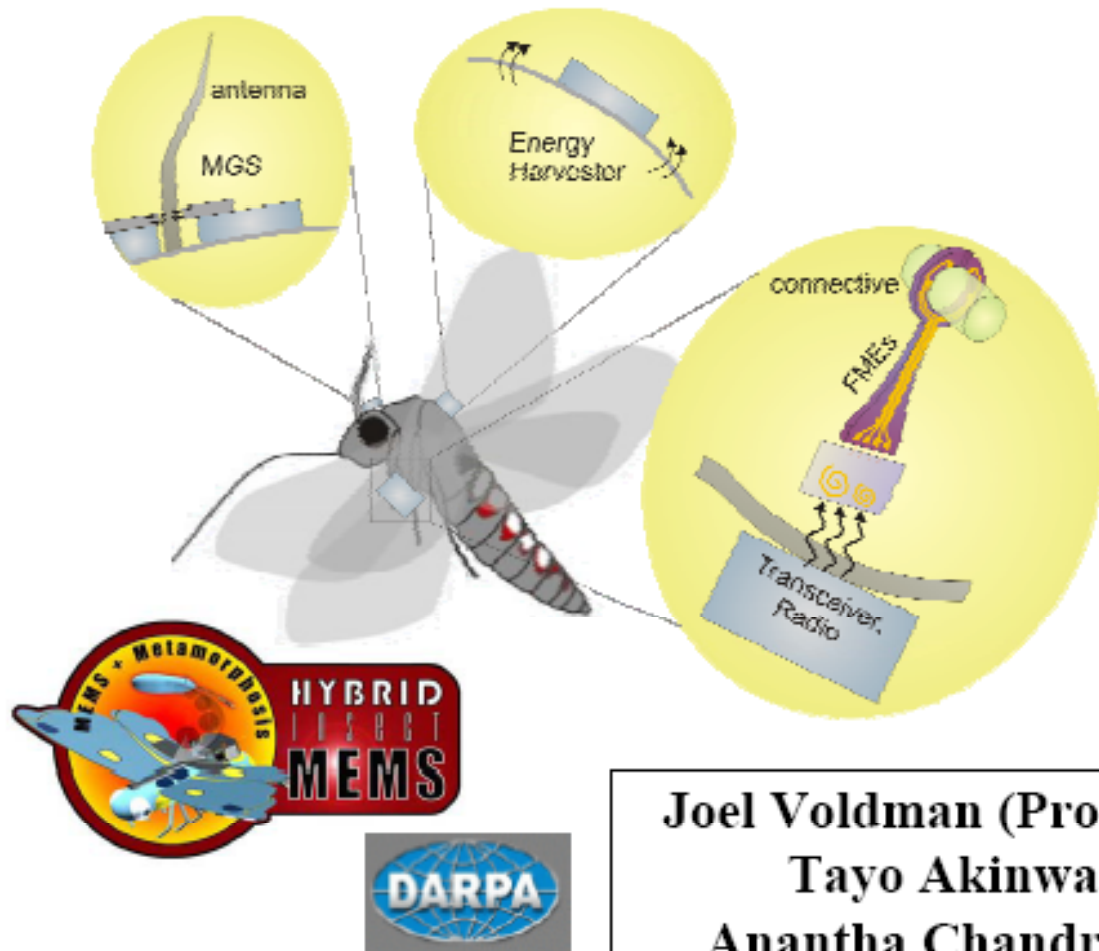
Challenges to be addressed:

- What materials are possible?
- What methods can be used for manufacturing?
- What devices are possible?
- How can we integrate these devices into systems?

Year 1 Activities:

- Optimized digital fabrication of electronic devices
- Demonstrate piezoelectrics
- Develop surface micromachining process
- Design Demo System
- Install 3D Printing Platform

Cyborg Moths: Melding Microelectromechanical Systems with Neurons for Motion Control in Freely Flying Insects



- Moth flight control with integrated electrodes and mechanical stimulation
- Energy harvesting from moth thorax motion
- Ultra-low power radio communications with base
- Implantation during development
- Growth of enhanced moths

Tom Daniel



Joel Voldman (Program PI)
Tayo Akinwande
Anantha Chandrakasan
Jeff Lang
Marty Schmidt



John Hildebrand
Goggy Davidowitz
Rick Levine



Industrial Membership



Industry Member Benefits

- Industrial Advisory Board(IAB)
 - 2x/year board meeting
- Research Symposia
 - 2x/year research conference
- Secured Web Site
 - Password protected
 - Contains streamed video conferences, publications, student theses, resumes
- Visits
 - Technology Transfer
- Recruiting
 - Resumes for graduating personnel and summer interns
- Technology Exchange
 - Facilitated access to technologies developed in the Center
- IP Report
 - An up-to-date summary of current MEMS IP available for license
- Publications
 - Provided on website include internal seminar slides, student theses publications and pre-publications

Research Symposia

- To be held 2x/year in conjunction with IAB meeting and MIT technology briefings
- Symposia output will be archived and made available to member companies
- Typical One-Day Agenda
 - Overview talks by industry, government, and academic leaders
 - Topics: Market opportunities, Funding opportunities, Research challenges
 - Round table discussions
- Expected outcome:
 - Partnering opportunities between MIT researchers and MEMS@MIT member companies
- *Symposia Topics*
 - ***Future Topics:***
 - ***MEMS for Implantable Medical Devices (Spring 2008)***
 - ***Wireless Sensors***

Fall 2006 Research Symposium

Micro/Nano Technology for Portable Power

- Future Power Needs in Portable Electronic Systems (Anantha Chandrakasan - MIT)
- High Power Density Power MEMS (Alan Epstein - MIT)
- MEMS Enabled Portable Power Systems (Klavs Jensen - MIT)
- Energy Harvesting (Jeff Lang - MIT)
- Nanostructured Thermoelectric Materials for Power Generation (Gang Chen - MIT)
- Developments in Photovoltaics (Emanuel Sachs - MIT)
- MEMS Solid Oxide Fuel Cell for Consumer Electronics (Sam Schaevitz – Lilliputian Systems)
- Opportunities in Batteries using Nanotechnology (Ric Fulop – A123 Systems)
- Panel Discussion – Investment Community Perspective
 - Dave Prend – Rockport
 - Jeff Andrews - Atlas



Spring 2007 Research Symposium

BioMEMS: Transforming Road Blocks to Guideposts on the Path to Innovation

- Microsystems in Blood Analysis and Sorting – Mehmet Toner (Harvard/MGH)
- Microdevices for Single Cell and Biomolecular Detection – Scott Manalis (MIT)
- Microfluidics as an Enabling Technology to Generate Biofunctional Barcoded Particles - Pat Doyle (MIT)
- Microtechnology for Manipulating Cells: Stem Cell Culture and Complex Phenotypic Cell Sorting - Joel Voldman (MIT)
- BioMEMS for Interrogating Multicellular Systems - Sangeeta Bhatia (MIT)
- Parallel Bioreactors with Controlled Microenvironments - Rajeev Ram (MIT)
- Microfluidic Tools for Cell Biology– Todd Thorsen (MIT)
- BioMEMS - Denny Freeman (MIT)
- BioMEMS Commercialization - Leon Sandler (Deshpande Center – MIT)
- Panel Session: Barriers in BioMEMS
 - Vern Norviel – Partner, Wilson Sonsini Goodrich & Rosati
 - Mark Lundstrom – CEO, BioScale
 - John Foster – CEO, IMT



Fall 2007 Research Symposium: Emerging Trends in MEMS/NEMS Manufacturing

Semiconductor Nanowires: Synthesis and Application - Professor Silvija Gradecak

Pattern Dependent Modeling of Polymer Microfluidics Manufacturing Processes — Professor Duane Boning (co-author Hayden Taylor)

NanoStructured Materials — Professor Vladimir Bulovic

Lithography Beyond the 10-nm Frontier — Professor Karl Berggren
Thermal Buoyancy Effect During the Carbon Nanotubes CVD Synthesis — Professor Jing Kong

Small-scale Nanopositioning Technologies that will Enable New Ways to Manufacture, Measure and Manipulate at the Micro- and Nano-scales — Professor Martin Culpepper

Nanostructured Origami — Professor George Barbastathis

Selective Self Assembly of Micro and Nano Systems — Professor Carol Livermore

Complexity in the Assembly of MEMS and Nanostructures — Professor Sang-Gook Kim



Fall 2007 IAB Agenda

| | |
|-------------|--|
| 8:30-8:45 | Continental Breakfast |
| 8:45-9:00 | Welcome, Introductions and Center Overview – Prof. Martin Schmidt |
| 9:00-9:40 | Hybrid Insect MEMS – Prof. Joel Voldman |
| 9:40-10:20 | A New DARPA Focus Center on Non-Lithographic Technologies for MEMS/NEMS – Prof. Martin Schmidt |
| 10:20-10:30 | Break |
| 10:30-11:10 | MEMS Technology for Advanced Thermal Management – Prof. Evelyn Wang |
| 11:10-12:00 | Center Activities Update and Feedback Review of Value Proposition New programs, Pending Proposals IP Web Content Recent Member Interactions Feedback |
| 12:00 | Adjourn |



Mark your calendar: Spring 2008 Open House April 22-23, 2008

Symposium Topic:

MEMS for Implantable Medical Devices



Spring 2008 Open House

- Tuesday, April 22nd
 - 9:00-5:00 MEMS for Implantable Medical Devices
 - Evening Board Dinner
- Wednesday, April 23rd
 - 9:00-12:00 Investigator Talks
 - 12:00-1:00 Lunch
 - 1:00-3:00 Poster Session
 - 3:00-3:30 Wrap-up Session



MEMS for Implantable Medical Devices

April 22nd, 2007

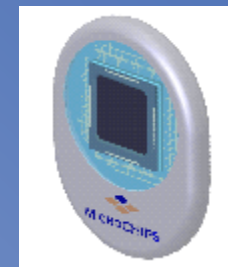
- Theme:
 - To explore opportunities and challenges in using MEMS for implantable medical devices
 - Medical monitoring
 - Therapy delivery
 - Neuro-stimulation
- Confirmed Speakers
 - Dr. Mark Allen: Implantable Pressure Sensor Technology
 - Founder of CardioMEMS
 - Dr. John Santini: Drug Delivery and Sensing Devices
 - Founder of MicroChips
 - Prof. John Wyatt: Retinal Implants
- Invitees
 - MEMS@MIT Members, Medical community, Industry reps from implantable market (e.g. Medtronic), Venture industry, Government funding agents



cardiomems™



MICROCHIPS™





Seminar Series


- Held weekly during the semester
- Speakers: Industry and Academic leaders
- All seminars are recorded and can be streamed afterwards from a password protected site accessible to any employee of a MEMS@MIT member company
- Examples of recent MEMS talks at MIT:
 - Dr. John Santini, MicroCHIPS, Inc., "Microchips for Implantable Drug Delivery and Biosensing"
 - Prof. Reza Ghodssi, U of Maryland, "Integrative MEMS Materials and Processes for Bio-Micro-Systems"
 - Prof. David Beebe, U. Wisconsin, "An Engineer's Foray into Cell Biology"
 - Prof. Gary Fedder, Carnegie Mellon, "Trends in CMOS MEMS"
 - Dr. David Soane, "Nanotechnology Applications for Mature Industries"
 - Prof. Luke P. Lee, UC Berkeley, "Nano and Microscale BioPOEMS"
 - Prof. David Walt, Tufts University, "Optical Sensor Microarrays"
 - Prof. Richard Mathies, UC Berkeley, "Microfabricated Chemical and Biochemical Analyzers: Terrestrial and Extraterrestrial Applications"
 - Prof. Ken Wise, U of Michigan, "Wireless Implantable Microsystems: Electronic Window on the Nervous System"
 - Prof. Martin Bazant, MIT, "Induced-Charge Electrokinetics"
 - Prof. Mark Shannon, U of Illinois, "Micro-Gas Chromatograph Analyzers"
 - Prof. Elisabeth Verpoorte, U of Groningen, "Understanding Recirculating Flows in Microfluidic Devices and their Application to Particle Separation"
 - Prof. Paul Alivisatos, UC Berkeley, "Nanocrystal Molecules"



MEMS@MIT | home - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address  http://mtlweb.mit.edu/mems/index.html 



MEMS@MIT

← Flow

100 μm 4 μm

RESEARCH AREAS:
Biological, Chemical, and Medical MEMS
Power MEMS
Enabling Technologies

search MEMS@MIT:

- Home
- Research
- Faculty Profiles
- Industrial Partnership
- News and Events
- Archived Materials
- Members Only**
- Links

Welcome to MEMS@MIT

We are a collection of faculty/staff/students working in the broad area of a Micro/nano systems and MEMS. This center was created to serve as a forum for collecting intellectually-synergistic but organizationally diverse groups of researchers at MIT. In addition, we have organized an industrial interaction mechanism to catalyze the transfer of knowledge to the larger MEMS community.

Currently, MEMS @ MIT is comprised of more than 125 faculty/staff/students, working on a broad research agenda and supported by more than \$13M/year of research contracts. Additionally, we share a set of world-class design, fabrication, and test facilities, including the more than 6,500 sq.ft. of cleanrooms that are managed by the Microsystems Technology Laboratories (MTL).

MEMS@MIT Open House: October 10-11, 2006

This one-day symposium brings together academic and industrial participants with the investment community to

- Home
- Research
- Faculty Profiles
- Industrial Partnership
- News and Events
- Archived Materials
- Members Only
- Links

MEMS@MIT Members Only

This site is provided for MEMS@MIT center members to add additional value to your membership. We currently offer links to streaming video of our seminars as well as links to other materials that may be of interest including other streaming video files and related research publications. We will be expanding this site to also include board meeting slides, resumes, intellectual property disclosures, and our center newsletter. We hope that you enjoy these exclusive materials!

MNSS Seminar Series Videos: Spring 2006

These streaming videos are all in RealMedia format. You will need to download [RealPlayer](#) in order to view them.



Thursday, March 9
Prof. David Beebe, U. Wisconsin,
"An Engineer's Foray into Cell Biology"
Video: [low](#) | [high](#)

Thursday, March 23
Prof. Gang Chen, MIT
"So, what does nanotechnology have to do with energy?"
Video: [low](#) | [high](#)

Thursday, April 6
Dr. John Kitching, NIST, Boulder,
"Chip-Scale Atomic Clocks"
Video: [low](#) | [high](#)

Thursday, May 11
Senturia Prize in MEMS/NEMS: Best Student Thesis
Mr. Anastasios John Hart, MIT Dept. of Mechanical Engineering
Synthesis of Carbon Nanotubes: Toward New Systems for Science and Manufacturing
Video: [low](#) | [high](#)

Related Videos from the MTL VLSI Seminar Series

April 25, 2006

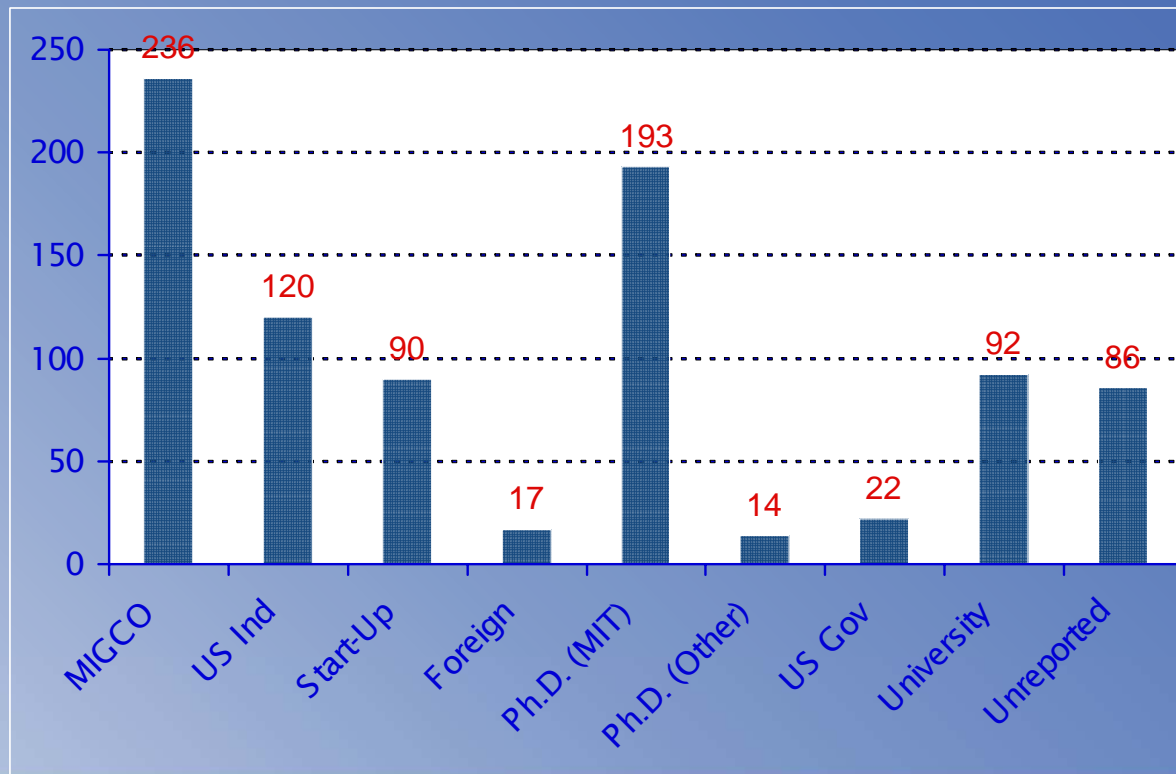


Recent MEMS IP (Available for Licensing)

- Low Voltage Flexible Organic/Transparent Transistor For Selective Gas Sensing, Photodetecting And Cmos Device Applications
- Control And Optimization Of Nanofluids Thermal Conductivity
- Monitoring Heparin By Microelectronic Devices
- Physical Vapor Deposited Nano-composites For Solid Oxide Fuel Cell Electrodes
- Continuous Biomolecule Separation In A Nanofilter
- Microfluidic Separators For Multiphase Fluid-flow Based On Membranes
- Method And Apparatus For High Throughput Diagnosis Of Diseased Cells With Microchannel Devices
- Apparatus And Methods For Controlled Growth And Assembly Of Nanostructures
- 6-axis Electromagnetically-actuated Meso-scale Nanopositioner
- Surface Phonon-polariton Raman Laser
- Production Of Reinforced Composite Materials And Aligned Carbon Nanotubes
- Resonant Dc-dc Converters
- Flow Cytometry And Immunodiagnostics With Mass Sensitive Readout
- Devices For Converting Electric Energy Into Energy Stored In The Mechanical Deformation Of Carbon Nanotubes And Back Again Into Electric Energy
- Guided-end Condition Method Used To Create Carbon Nanotube-based Mechanisms

Graduate Recruiting

- Historically, participation in industrial centers have proven to be a very high impact tool for recruiting
- Example:
 - MTL Industrial Group (MIG) – 1990-2003: 12 US Companies



Recent Member Interactions

- HP-MIT-OSU
 - Substantial interactions through Focus Center
- Alps Electric
 - Visitor (Kurt Ozaki) here for 3 months for wafer bonding technology transfer
- NEC
 - Visitor (Takeshi Honda) here for one year for MEMS design activities
- Bosch
 - Sponsoring BioMEMS project with Prof. Manalis



Why should my company join?

- Insight to newest ideas in MEMS
 - Through our 2x/year meetings and web-based dissemination of information, your organization will get rapid insight to areas we feel are important in MEMS. You can interact with leaders in the field and learn about the newest areas of research first hand.
- Early access to research results
 - You will be afforded the chance to learn of our work as soon as it is publicly accessible. This access will be through direct exchange with our campus researchers.
- Intellectual Property
 - The center membership is priced at a point where we will not be providing IP rights. However, a large fraction of our overall research is supported through governments or foundations. In most of these cases, the IP that results is available for licensing. We will produce a quarterly '**MEMS IP Report**' which summarizes all the MEMS-related IP which is available for license. Participation in MEMS@MIT will give you the awareness of when this IP is being generated so that you can engage the MIT Technology Licensing Office (TLO) early.
- Continuing Education
 - Web-based materials such as publications, reports, and theses can be very valuable learning tools for your personnel. More importantly, there is the ability for any employee in your organization to stream seminars from world leaders on a diversity of topics at any time.
- Partnering
 - As a result of our close working relationship through the Center, we see opportunities to partner with you in pursuit of federal or other funding opportunities.
- Facilities/Technology Access
 - With such a large pool of activities, we support a diverse range of technologies. Should you wish to visit and learn in more detail about our technologies, the MEMS@MIT administration will facilitate such visits. If you wish to use the MIT fabrication facilities, programs exist to support this, and MEMS@MIT can direct you to those programs.
- Recruiting
 - We graduate a large number of advanced degree students annually. These students are highly sought after upon graduation. As a member of the center, you will have the chance to meet and interact with these people substantially throughout their graduate career. History has shown that this typically leads to great success in recruiting these students upon graduation.

How do I learn more? How do I join?

- Membership in the Center is \$50K/year
- Should you wish any more information, or are ready to join, please contact the Manager of Administration and Liaison: Ms. Anne Wasserman at annew@mit.edu or the Center Director: Prof. Martin A. Schmidt at schmidt@mtl.mit.edu
- An up-to-date summary of all the MEMS research at MIT can be located at our web site: www.mtl.mit.edu/mems