

ME 517: Micro- and Nanoscale Processes

Lecture: Introduction

Steven T. Wereley

Mechanical Engineering

Purdue University

West Lafayette, IN USA

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Unifying themes in ME/CHE517

- Continuum breakdown
 - In each physical process studied, where does the atomic nature of matter become important?
- Pairwise atomic interaction potential
 - For many of the processes we will start with how atoms interact and go up as well as down
- Atomic force microscopy will be used as a prototypical nanotech system in which MEMS tools are necessary to study nanoscales

Micro/Nano Classes at Purdue

- Wereley:
 - ME517 Micro/nano Physical Processes
 - ME697W small-scale fluid mechanics
- Tim Fisher: ME597F Micro/nano Energy Transfer Processes
- Ziaie/Savran: ECE595B MEMS and Micro-Integrated Systems
- David Janes: ECE557 Microfabrication
- Ivansivec/Raman: AFM course(s)
- Birck staff: SEM course

The *Big Picture*: Dictionary Definitions

- Main Entry: micro-
 - Etymology: International Scientific Vocabulary, from Greek *mikros* meaning small
 - one millionth (10^{-6}) part of <*micrometer*>
- Main Entry: nano-
 - Etymology: International Scientific Vocabulary, from Greek *nanos* meaning dwarf
 - one billionth (10^{-9}) part of <*nanometer*>
- We will see that these scales are important indicators in determining when systems behave differently from macroscopic expectations

What is Nanotechnology?

- Called many different things:
 - Nanoscale Science and Engineering,
Nanotechnology, Molecular Nanotechnology, ...
- According to the *National Nanotechnology Initiative*, Nanotech is “research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1 - 100 nanometer range, to provide a fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices and systems that have novel properties and functions because of their small and/or intermediate size. *The novel and differentiating properties and functions are developed at a critical length scale of matter typically under 100 nm.*

The Scale of Things – Nanometers and More

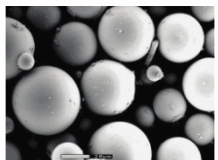
Things Natural



Dust mite
200 μm



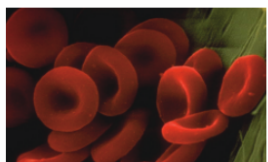
Ant
~ 5 mm



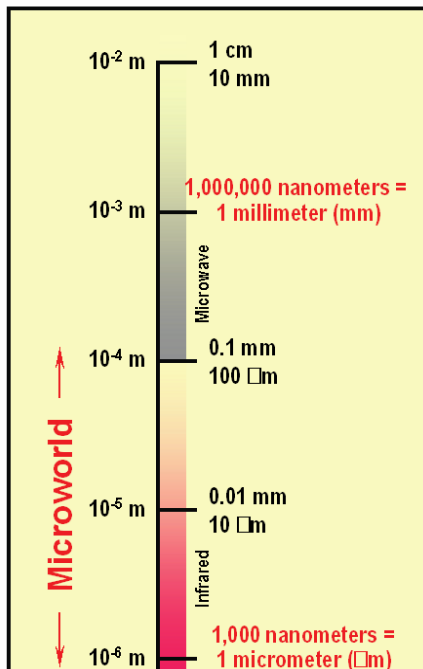
Fly ash
~ 10-20 μm



Human hair
~ 60-120 μm wide



Red blood cells
(~7-8 μm)



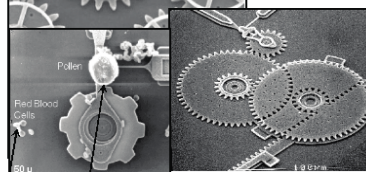
Things Manmade



Head of a pin
1-2 mm

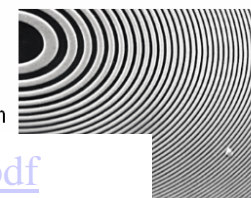


MicroElectroMechanical (MEMS) devices
10-100 μm wide

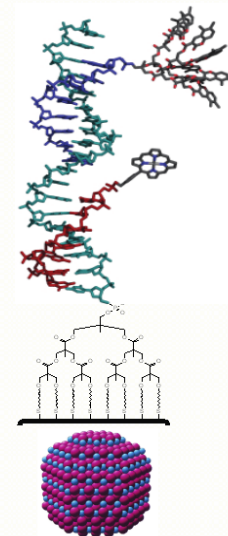


Pollen grain
Red blood cells

Zone plate x-ray "lens"
Outer ring spacing ~35 nm

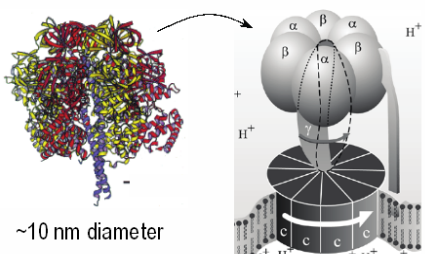


The Challenge



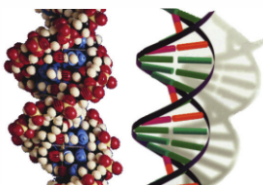
Fabricate and combine nanoscale building blocks to make useful devices, e.g., a photosynthetic reaction center with integral semiconductor storage.

http://science.energy.gov/~media/bes/pdf/scale_of_things_26may06.pdf

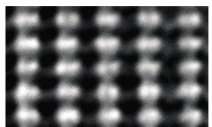


~10 nm diameter

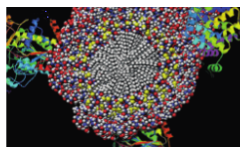
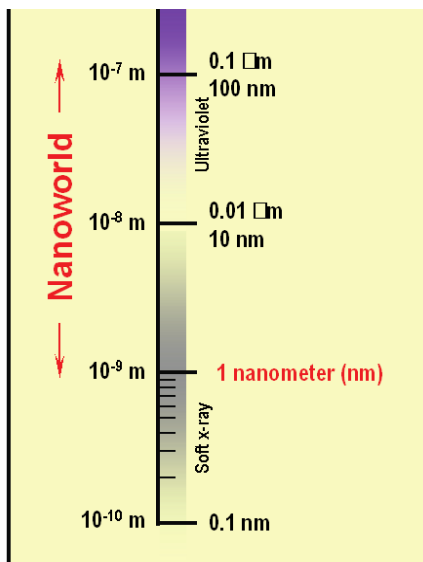
ATP synthase



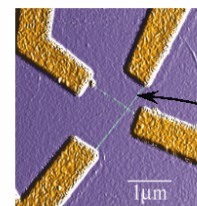
DNA
~2-1/2 nm diameter



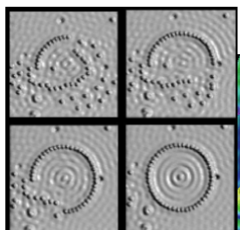
Atoms of silicon
spacing 0.078 nm



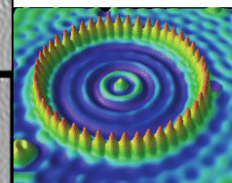
Self-assembled, Nature-inspired structure
Many 10s of nm



Nanotube electrode



Quantum corral of 48 iron atoms on copper surface
positioned one at a time with an STM tip
Corral diameter 14 nm



Carbon nanotube
~1.3 nm diameter

Carbon buckyball
~1 nm diameter

What is MEMS?

Methodology

“MEMS is a way of making things” (DARPA). These things merge the functions of sensing and actuation with computation and communication to locally control physical properties at the microscale, yet cause effects at much grander scale.

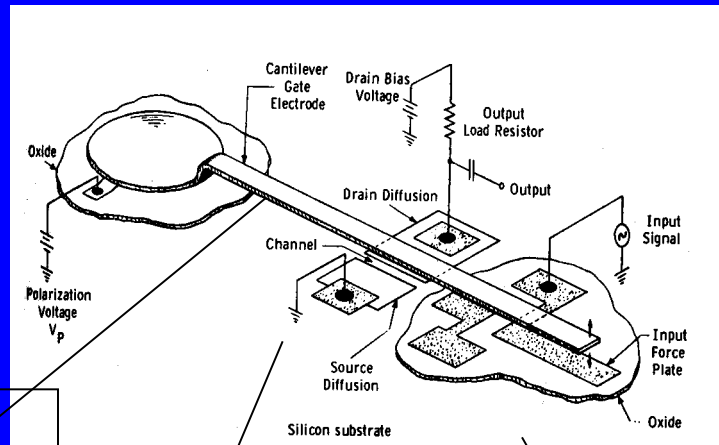
MEMS is an enabling technology for many nanotech processes

When did MEMS Start?

'The Resonant Gate Transistor', H.C. Nathanson, W.E. Newall, R.A. Wickstrom,
J.R. Davis, IEEE Transactions on Electron Devices, 3, 117-133, 1967.

Westinghouse Research Labs

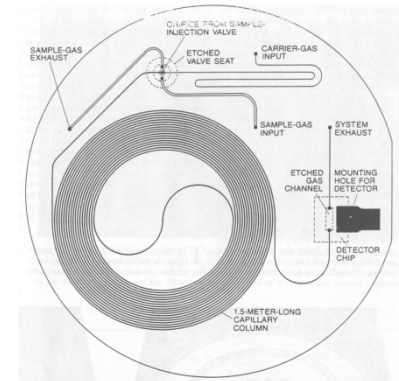
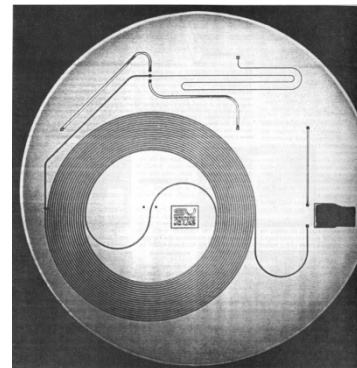
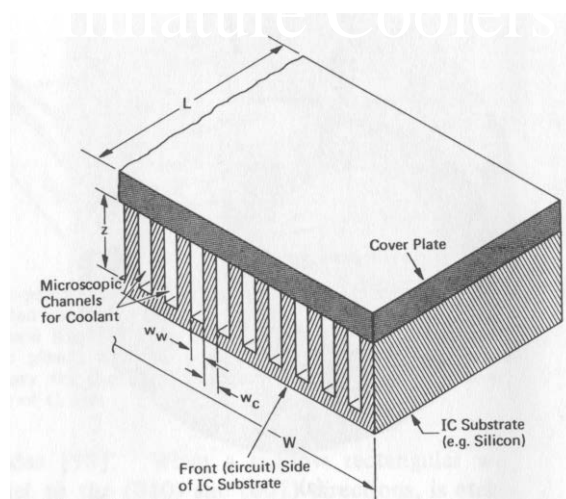
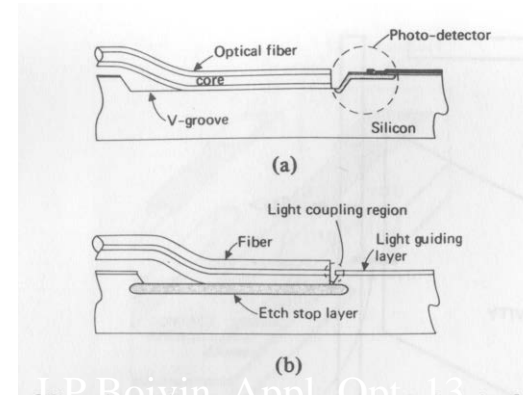
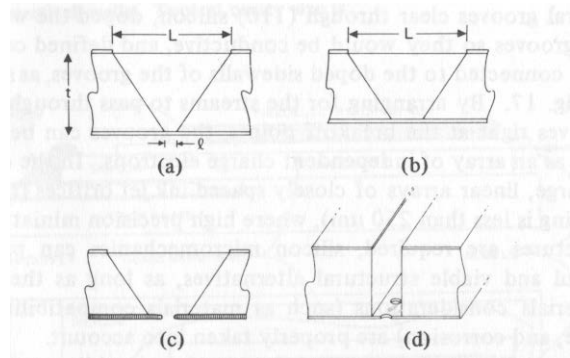
Application: integrated tuning device - capacity of high Q.



Mechanical resistor with desired Q. Output transistor to sense the motion of the mech. resonator and generate signal.

Input transistor to convert the input electrical signal into a mechanical force (electrostatic).

What was MEMS circa 1982?

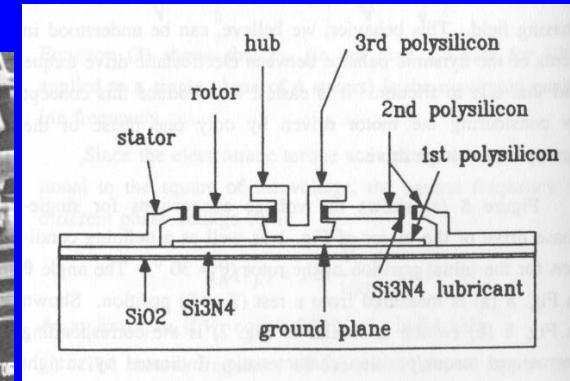
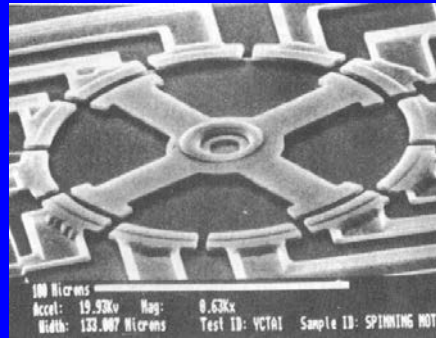


What was MEMS circa 90s?

Actuators

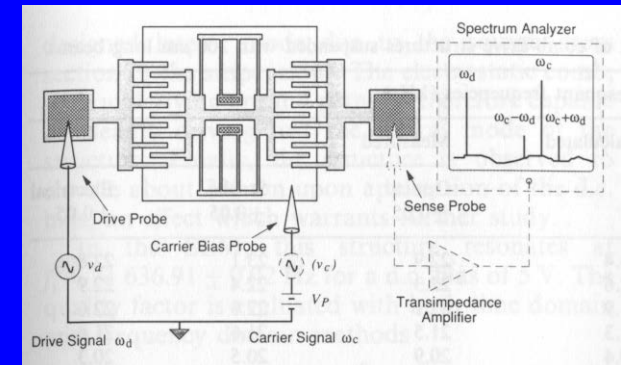
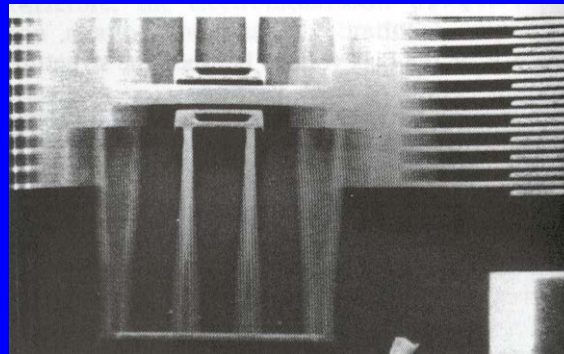
Slide drive actuators

LS Fan, et al, IEEE Inter. Electron. Devices Meeting, 666, 1988



Comb drive actuators

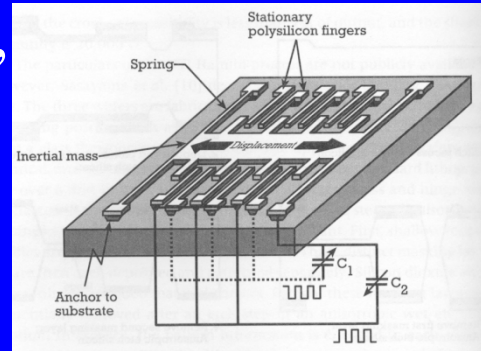
WC Tang, et al, IEEE MEMS, 53, 1989



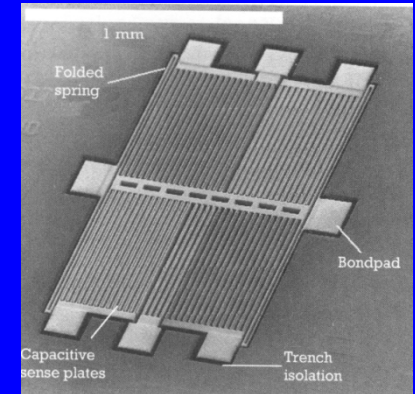
Electrostatic, Magnetic, Harmonic, Thermal, Shape Memory, Impact and PZT actuators

What is MEMS today?

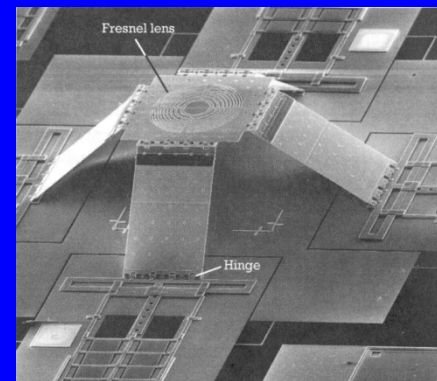
- Engine and propulsion control.
- Automotive safety, braking, and suspension systems.
- Distributed sensors monitoring structural health.
- Distributed control of aerodynamics
- Telecommunication optical fiber components and switches
- Electromechanical signal processing.
- Mass data storage systems.
- Biomedical systems



Analog Devices, Inc, Norwood, MA



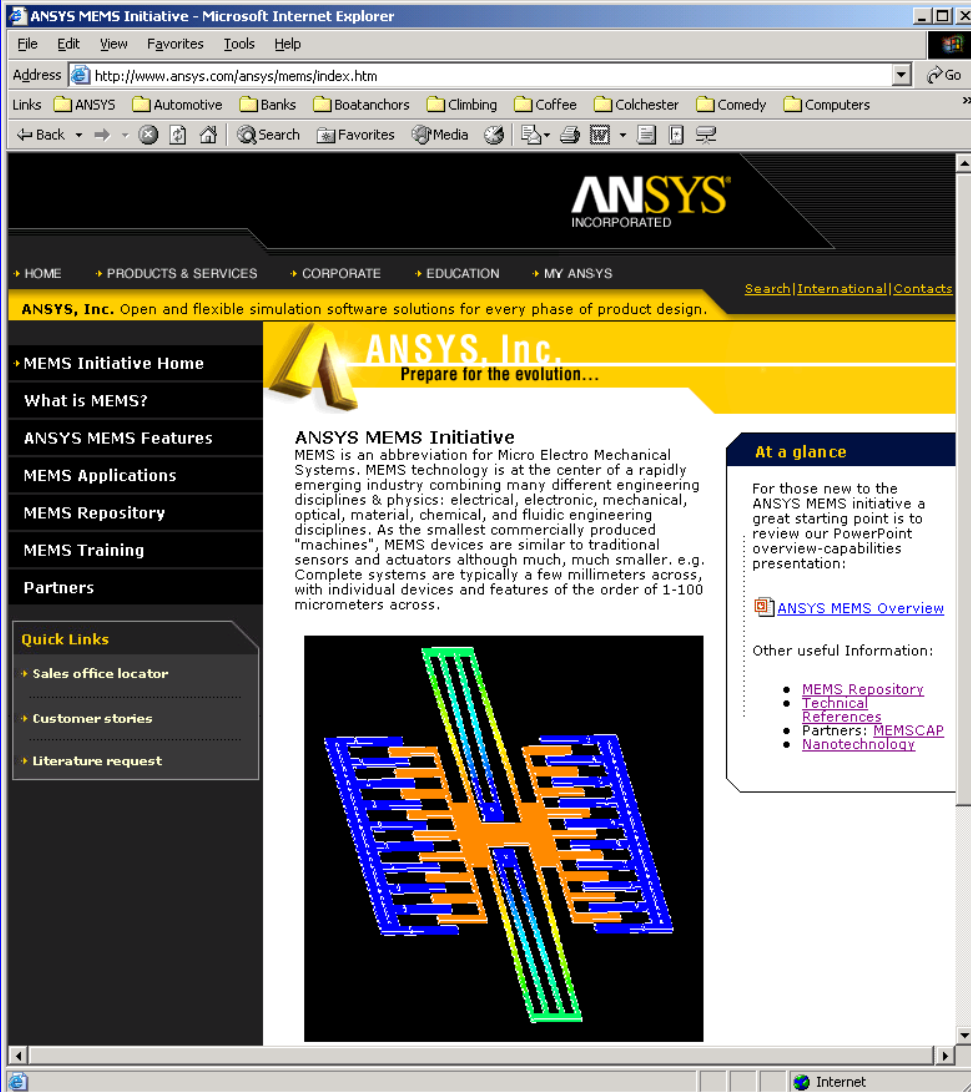
Lucas NovaSensor, Fremont, CA



M.C Wu, Proceedings of the IEEE, 86, 1705, 1998.

The ANSYS multiphysics simulations

www.ansys.com



The screenshot shows a Microsoft Internet Explorer browser window displaying the ANSYS MEMS Initiative website. The browser's address bar shows the URL <http://www.ansys.com/ansys/mems/index.htm>. The website features the ANSYS logo at the top, followed by a navigation menu with links to HOME, PRODUCTS & SERVICES, CORPORATE, EDUCATION, and MY ANSYS. A search bar and a 'Go' button are also present. Below the navigation, a yellow banner reads 'ANSYS, Inc. Open and flexible simulation software solutions for every phase of product design.' The main content area is titled 'ANSYS, Inc. Prepare for the evolution...' and includes a section for the 'ANSYS MEMS Initiative'. This section defines MEMS as an abbreviation for Micro Electro Mechanical Systems and describes the industry as rapidly emerging, combining various engineering disciplines. A 3D CAD model of a MEMS device is shown below the text. To the right, a 'At a glance' box provides a starting point for new users, including a link to the 'ANSYS MEMS Overview' and a list of other useful information such as 'MEMS Repository', 'Technical References', 'Partners: MEMSCAP', and 'Nanotechnology'. A left-hand sidebar contains navigation links for 'MEMS Initiative Home', 'What is MEMS?', 'ANSYS MEMS Features', 'MEMS Applications', 'MEMS Repository', 'MEMS Training', and 'Partners'. A 'Quick Links' section at the bottom of the sidebar includes 'Sales office locator', 'Customer stories', and 'Literature request'.

Assignment for Next Class

1. Log onto the Blackboard website (*and figure out how to use it*).
2. Email me the following information:
 1. Education level and degree(s)
 2. Background in the areas mentioned in the syllabus (other courses, area of research, work experience, etc)
 3. A brief list of your course hopes/expectations
3. Read
 1. Feynman's "Plenty of room at the bottom"
<http://www.zyvex.com/nanotech/feynman.html>
 2. Trimmer's "The Scaling of Micromechanical Devices"
<http://home.earthlink.net/~trimmerw/mems/Scale.html>