EE C247B – ME C218
Introduction to MEMS Design
Spring 2019

Prof. Clark T.-C. Nguyen

Dept. of Electrical Engineering & Computer Sciences
University of California at Berkeley
Berkeley, CA 94720

Lecture Module 1: Admin & Overview

Instructor: Prof. Clark T.-C. Nguyen

- *Education*: Ph.D., University of California at Berkeley, 1994
- *1995*: joined the faculty of the Dept. of EECS at the University of Michigan
- *2006*: (came back) joined the faculty of the Dept. of EECS at UC Berkeley
- *Research*: exactly the topic of this course, with a heavy emphasis on vibrating RF MEMS
- *Teaching*: (at the UofM) mainly transistor circuit & physics; (UC Berkeley) 140/240A, 143, 243, 245,247B/ME218
- *2001*: founded Discera, the first company to commercialize vibrating RF MEMS technology
- *Mid-2002 to 2005*: DARPA MEMS program manager
  - ran 10 different MEMS-based programs
  - *topics*: power generation, chip-scale atomic clock, gas analyzers, nuclear power sources, navigation-grade gyros, on-chip cooling, micro environmental control

Course Overview

- Goals of the course:
  - Accessible to a broad audience (minimal prerequisites)
  - Design emphasis
    - Exposure to the techniques useful in analytical design of structures, transducers, and process flows
  - Perspective on MEMS research and commercialization circa 2019
- Related courses at UC Berkeley:
  - EE 143: Microfabrication Technology
  - EE 147/247A: Introduction to MEMS
  - ME 119: Introduction to MEMS (mainly fabrication)
  - BioEng 121: Introduction to Micro and Nano Biotechnology and BioMEMS
- Assumed background for EE C247B/ME C218:
  - graduate standing in engineering or physical/bio sciences
  - knowledge of microfabrication technology

Course Overview

- The mechanics of the course are summarized in the course handouts, described in lecture today
  - Course Information Sheet
    - Course description
    - Course mechanics
    - Textbooks
    - Grading policy
  - Syllabus
    - Lecture by lecture timeline w/ associated reading sections
    - Midterm Exam: Thursday, March 21
    - Final Exam: Thursday, May 16, 8-11 a.m. (Group 13)
    - Project due date TBD (but near semester's end)

What Should You Know?

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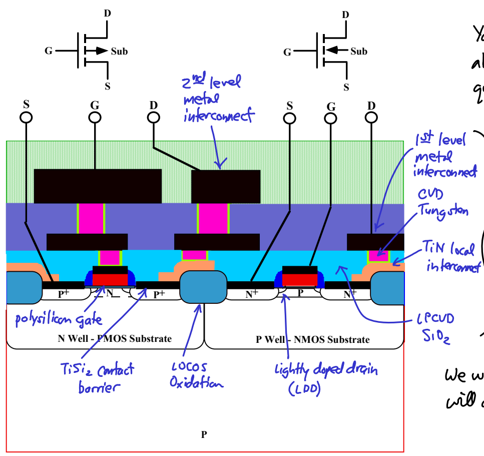
Typical mid-2000's CMOS Process (good down to ~0.25μm)



You should either already know or be able to learn independently & very quickly:

1. How to deposit or grow these different layers.
2. How to pattern or otherwise form the shapes of the layers shown.
3. What determines the order by which the different layers are formed, e.g., temperature limits, topography limits, etc...

We will review these things, but we will do this very fast!

What Should You Know?

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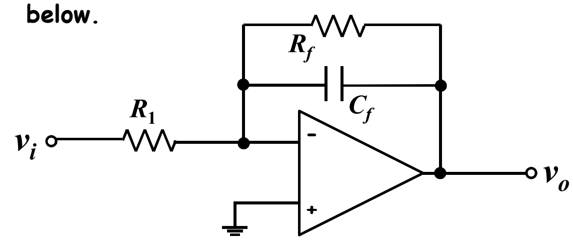
- Basic circuit analysis & design using op amps
- *Example*: Find the transfer function $v_o(s)/v_i(s)$ of the circuit below.



Lecture Outline

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- Reading: Senturia, Chapter 1
- Lecture Topics:
  - Definitions for MEMS
  - MEMS roadmap
  - Benefits of Miniaturization

MEMS: Micro Electro Mechanical System

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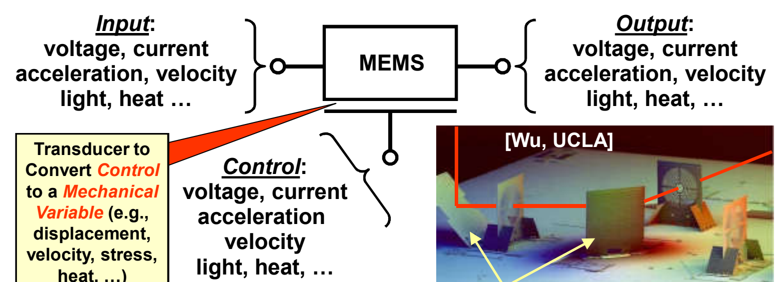
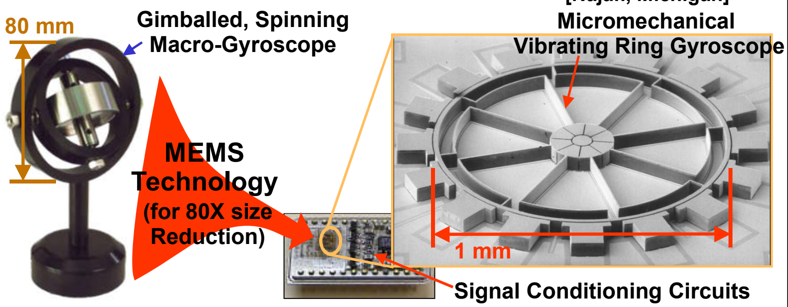
- A device constructed using micromachining (MEMS) tech.
- A micro-scale or smaller device/system that operates mainly via a mechanical or electromechanical means
- At least some of the signals flowing through a MEMS device are best described in terms of mechanical variables, e.g., displacement, velocity, acceleration, temperature, flow



Angle set by mechanical means to control the path of light

Other Common Attributes of MEMS

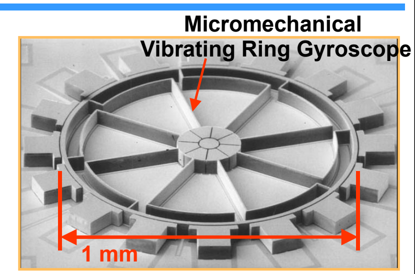
- Feature sizes measured in microns or less



- Merges computation with sensing and actuation to change the way we perceive and control the physical world
- Planar lithographic technology often used for fabrication
  - can use fab equipment identical to those needed for IC's
  - however, some fabrication steps transcend those of conventional IC processing

Bulk Micromachining and Bonding

- Use the wafer itself as the structural material
- *Adv*: very large aspect ratios, thick structures
- *Example*: deep etching and wafer bonding



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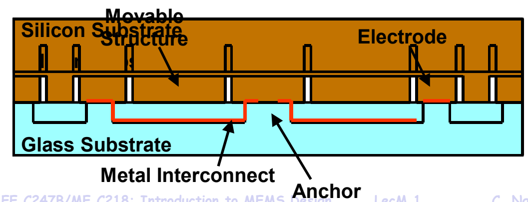
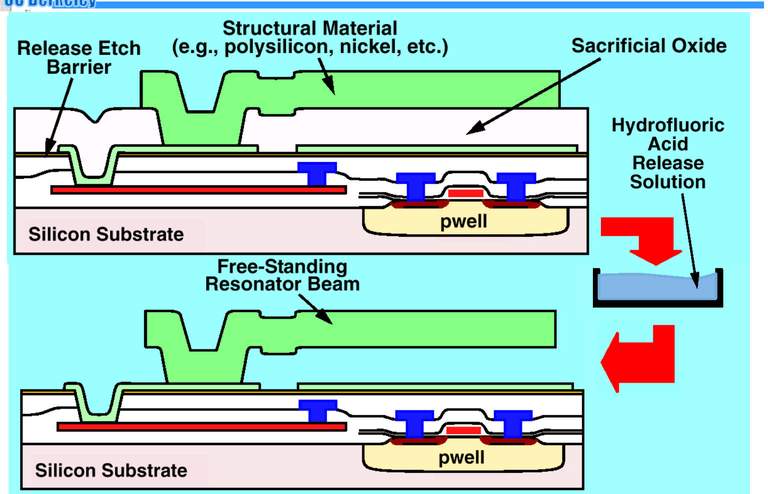


Microrotor (for a microengine)

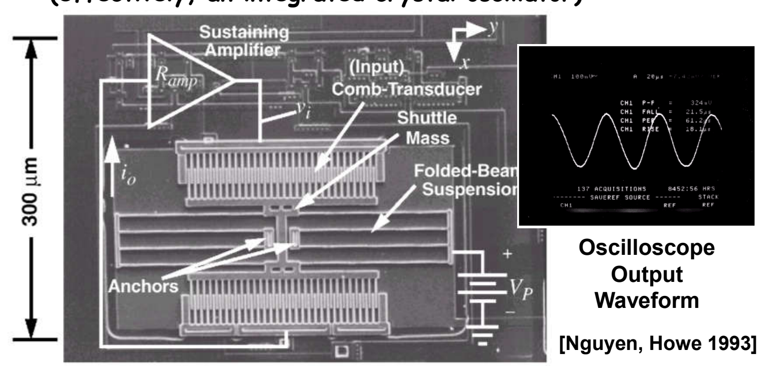
Surface Micromachining



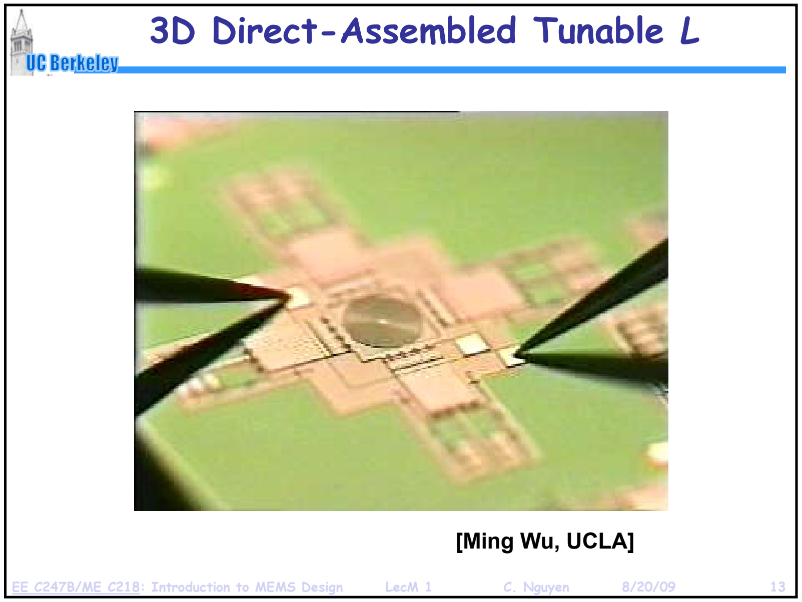
- Fabrication steps compatible with planar IC processing

Single-Chip Ckt/MEMS Integration

- Completely monolithic, low phase noise, high-Q oscillator (effectively, an integrated crystal oscillator)



- To allow the use of >600°C processing temperatures, tungsten (instead of aluminum) is used for metallization


3D Direct-Assembled Tunable L
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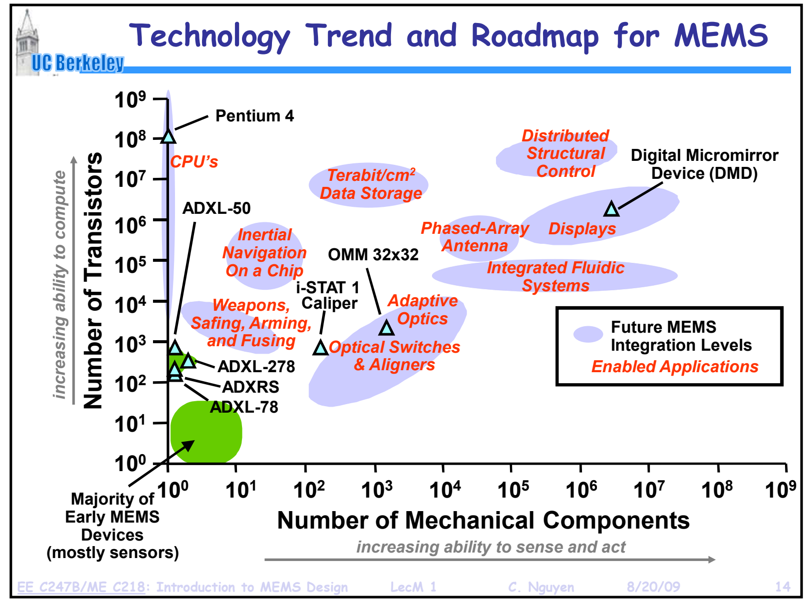
Technology Trend and Roadmap for MEMS
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Number of Transistors
increasing ability to compute
Number of Mechanical Components
increasing ability to sense and act
Pentium 4
CPU's
ADXL-50
Inertial Navigation On a Chip
Terabit/cm² Data Storage
Distributed Structural Control
Digital Micromirror Device (DMD)
Phased-Array Antenna
Displays
Integrated Fluidic Systems
OMM 32x32
i-STAT 1 Caliper
Adaptive Optics
Weapons, Safing, Arming, and Fusing
Optical Switches & Aligners
ADXL-278
ADXRS
ADXL-78
Majority of Early MEMS Devices (mostly sensors)
Future MEMS Integration Levels
Enabled Applications
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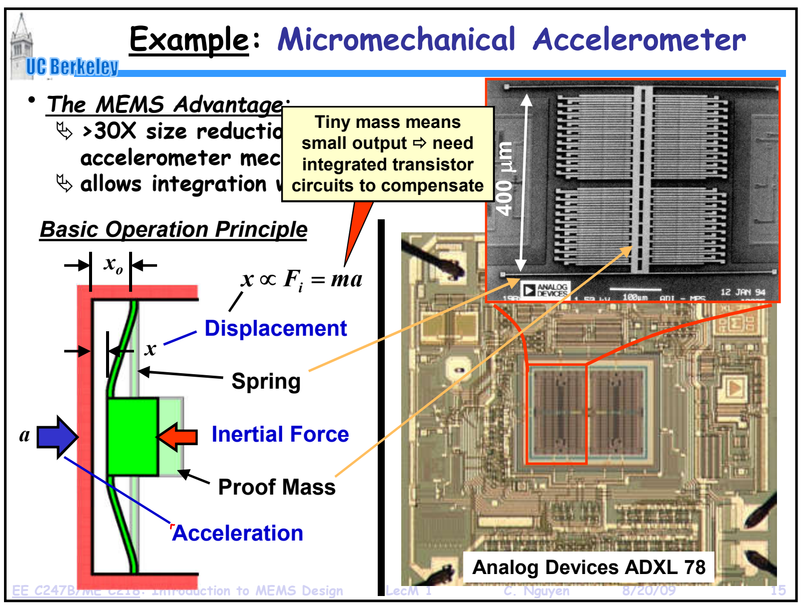
Example: Micromechanical Accelerometer
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The MEMS Advantage:
>30X size reductio
accelerometer mec
allows integration w
Tiny mass means small output ⇨ need integrated transistor circuits to compensate
Basic Operation Principle
$x \propto F_i = ma$
Displacement
Spring
Inertial Force
Proof Mass
Acceleration
400 µm
Analog Devices ADXL 78
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