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 2015
• 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
  △ ME C219 - EE C246: MEMS Design
• 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, given out 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 17
    • Final Exam: Thursday, May 12, 8-11 a.m. (Group 13)
    • Project due date TBD (but near semester's end)
What Should You Know?

P Well - NMOS Substrate
N Well - PMOS Substrate

What Should You Know?

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

Lecture Outline

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

MEMS: Micro Electro Mechanical System

* 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

Input: voltage, current, acceleration, velocity, light, heat, ...

MEMS

Output: voltage, current, acceleration, velocity, light, heat, ...

Transducer to Convert Control to a Mechanical Variable (e.g., displacement, velocity, stress, heat, ...)

Control: voltage, current, acceleration, velocity, light, heat, ...

Angle set by mechanical means to control the path of light

[Wy, UCLA]
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

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
Example: Micromechanical Accelerometer

- **The MEMS Advantage:**
  - >30X size reduction
  - accelerometer mechanics allows integration

**Basic Operation Principle**

\[ x \approx F_i = ma \]

Displacement \( x \) x-axis

Inertial Force \( F_i \)

Spring

Proof Mass

Acceleration \( a \)

**ADXL78**

Tiny mass means small output \( \Rightarrow \) need integrated transistor circuits to compensate.