EE M250B
MEMS PHYSICS & DESIGN

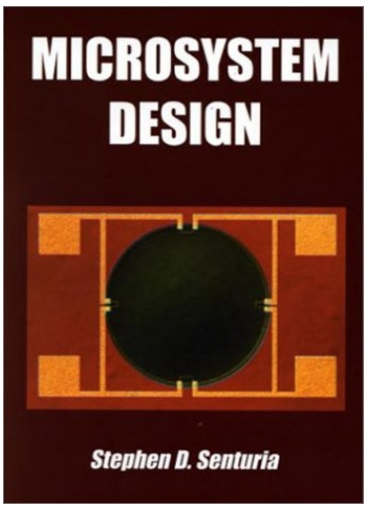
Spring 2003
MW 2:00 – 3:50 pm
9436 Boelter Hall

Ming C. Wu
UCLA Electrical Engineering Department
Los Angeles, CA 90095-1594
wu@ee.ucla.edu

Scope

- Introduction to MEMS design
  - Design methodology, design rules
- Sensing and actuation mechanisms
- Microsensors, and microactuators
- Designing MEMS with both foundry and custom processes
- Case study of MEMS products

Textbook



- Microsystem Design
  - Steve Senturia (MIT)
  - First published in 2001
  - Kluwer Academic Publishers
  - ISBN 0-7923-7246-8
- Emphasis on
  - Physics
  - Modeling
  - CAD
  - Detailed case studies

Reference Books

- Greg Kovacs, *Micromachined Transducers Sourcebook*, McGraw Hill, 1998
  - Covers a wide range of topics
  - Comprehensive list of references
- N. Maluf, *An Introduction to Microelectromechanical Systems Engineering,* Artech House, 2000
  - Intended for use as an introductory textbook
- T.R. Hsu, *MEMS and Microsystems*, McGraw-Hill, 2002
  - Introductory textbook
- *Micromechanics and MEMS, Classic and Seminal Papers to 1990*, Edited by W. S. Trimmer, 1997 (IEEE Press)
- Research papers listed on the web:
  - www.ee.ucla.edu/~wu/ee250b/

Background

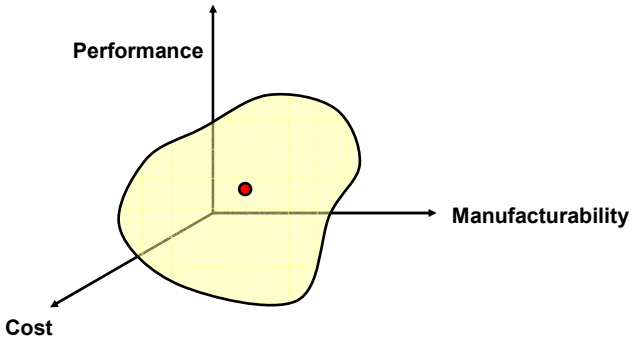
- Basic MEMS fabrication processes
  - Prerequisite: EE M250A (MAE 280)
  - May be substituted by EE M150L
- Layout tool
  - Have access to a layout tool such as L-Edit, Cadence, Magic, etc.
  - If you don't have access, you need to find a partner
- Mathematical tools
  - Familiar with and have access to at least one of the following numerical packages (or its equivalent):
    - MathCAD
    - MATLAB
- Knowledge of MEMS CAD package (such as MEMCAD, ANSIS, IntelliCAD, etc.) is a plus but not required

Topics Covered in This Course

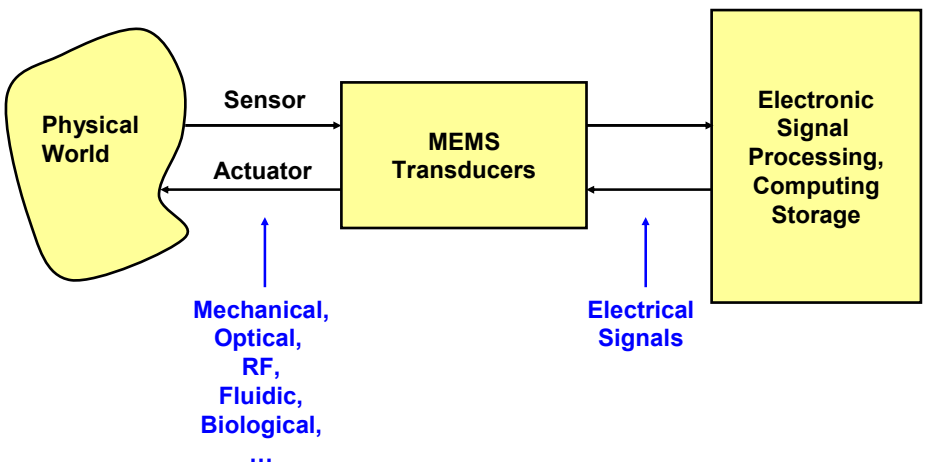
- Transduction principles:
  - Mechanical
  - Electrostatic
  - Magnetic and Electromagnetic
  - Thermal
  - Piezoelectric
  - Fluidic
- Applications and Case Studies:
  - Inertia sensors
    - Capacitive accelerometers
    - Piezoelectric rate gyros
  - Pressure sensors (piezoresistive)
  - Projection display
    - Digital Micromirror Devices
    - Grating Light Valve (GLV)
  - Optical switching
    - 2D MEMS switch
    - 3D MEMS switch
  - RF MEMS
    - RF switches
    - Tunable capacitors

What is Design?

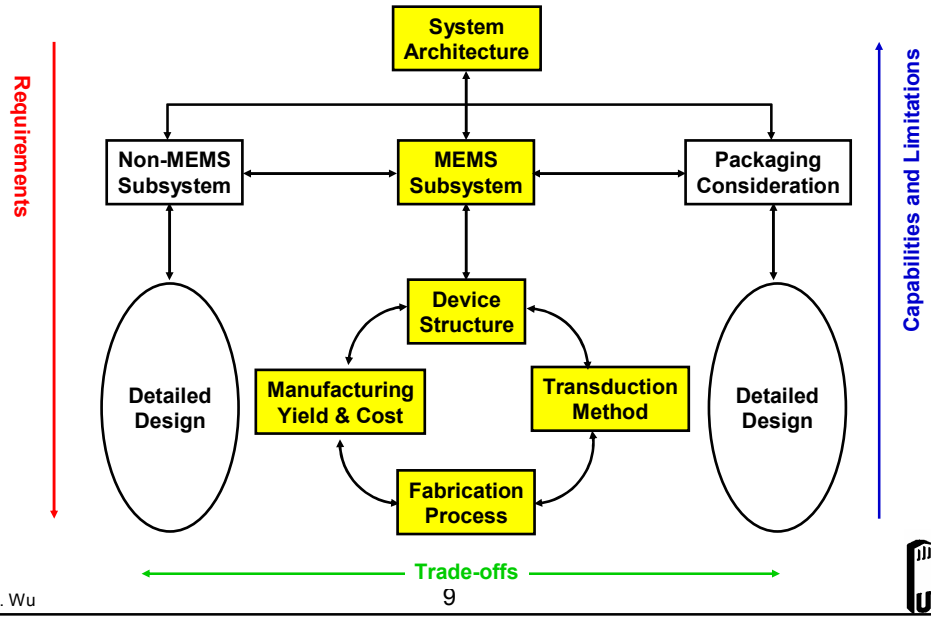
- Find a solution that satisfies a set of boundary conditions
  - The boundary conditions usually have conflicting requirements
  - Trade-offs have to be made
  - Performance is not the only goal. It is often traded off for manufacturability



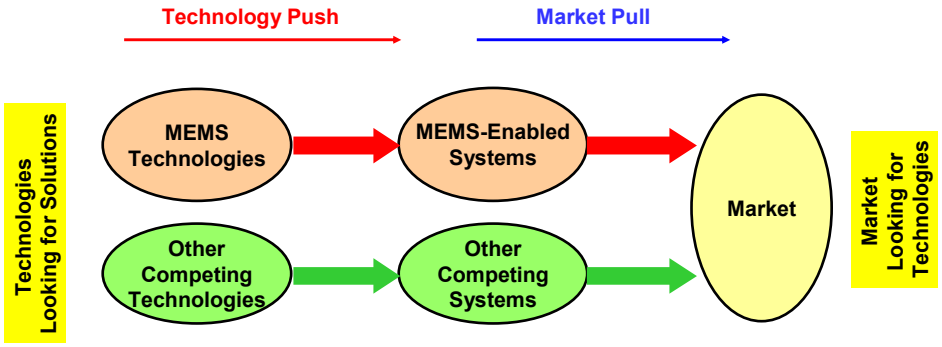
MEMS System



What is MEMS Design?



High Level Design Issues
(Before You Start Designing MEMS)

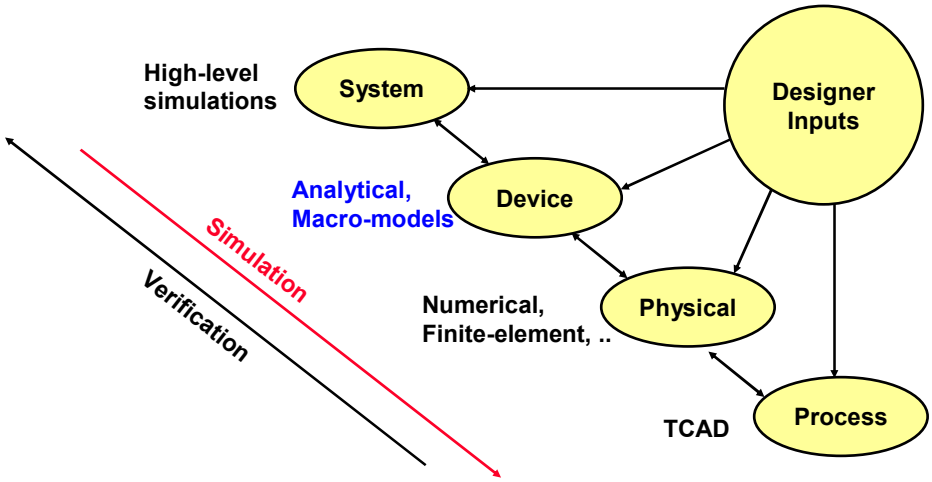


- Competition with both conventional technologies and other MEMS producers
- Manufacturability
- Cost

- Is MEMS the best solution?
- Does it have high impact?
- Does MEMS produce a paradigm shift?

- Real need for the market
- Who are the customers?
- Market size
- Market timing
- Mass or niche market?
- Technology available?

MEMS Design and Modeling



MEMS Design Flow

System Requirements	Device Design	Implementation	Layout
• Sensitivity • Responsivity • Freq response • Loss • Power consumption • etc	• Transduction mechanism • Physical simulation • Verify system requirement	• What technology to use? – Bulk vs surface micromachining – Custom vs Foundry processes – Materials (Si, single crystal, poly, …) • Process integration	• Establish technology files – Layers of materials – Thickness – Deposition or etching – Lithography • Mask layout • Design rules
• System level simulation (e.g. optical simulation for optical systems)	• Analytical models • Macro models	• Finite element method • Coupled domain FEM (MEMCAD, ANSIS, IntelliCAD, ..)	• Design rule checking (DRC) • Cross-section view • Synthesis • Export to MEMS CAD

MEMS Design Flow (cont'd)

Fabrication	Testing	Reliability
• Process simulation	• Labview • Automatic testing • Establish database	