

Principles of MEMS Transducers

Huikai Xie

Department of Electrical Engineering
University of Florida

Introduction and Orientation

■ Agenda:

- ↗ Introduction
- ↗ Syllabus
- ↗ MEMS
 - Orientation

📖 Next time: Reading: Senturia, pp. 1-14.

Introduction

- Instructor: Prof. Huikai Xie
 - Dept. of Electrical and Computer Engineering
 - Office: 221 Benton Hall
 - Email: hkx@ufl.edu
 - Office hours: 10:40am-12:00pm MWF
- TA:
 - Hongwei Qu (hwqu@ufl.edu)
 - Office hours: TBA
- Guest Instructors:
 - Prof. Toshi Nishida (nishida@ufl.edu)
 - Prof. Mark Sheplak (ms@aero.ufl.edu)

Syllabus (1)

1. COURSE TITLE: Principles of MEMS Transducers
2. INSTRUCTOR: Dr. Huikai Xie; 221 Benton; 846-0441;
hkx@ufl.edu
3. TEXTBOOK: Stephen D. Senturia, *Microsystem Design*
(Kluwer Academic Publishers, Boston, 2001)
4. WWW site: <http://www.mems.ece.ufl.edu/EEL5225>
5. SOFTWARE: Coventorware, PSPICE, Matlab
6. HOMEWORK: Homework problems will be assigned on a weekly or biweekly basis. It's OK to talk about the class and the assignments with your friends. It's not OK to just copy their work. Cheating and plagiarism will be punished according to UF's standard procedures. Late homework is only accepted with permission of instructor, and will be graded with a 20% reduction per day.
7. GRADING: 20% Homework, 40% 2 Tests, 40% Design Project
Tentative schedule for the two tests: Test 1 (10/6); Test 2 (11/17)
50 minutes for each test, closed-book, one formula sheet allowed.

Syllabus (2)

- Goals: To analyze and design MEMS transducers utilizing principles of sensing and actuation, properties of materials available for fabrication, microfabrication technologies, and understanding of circuit and system issues, packaging, calibration, and test.

- Topics:
 - Introduction and Orientation (1)
 - Sensors and Actuators Technologies (1)
 - Fabrication Technology, Part I (2)
 - Fabrication Technology, Part II (4)
 - Transduction Mechanisms (7)
 - Modeling (6)
 - Dynamics (2)
 - Interface Circuits for Sensors (5)
 - Case Studies (8)
 - Accelerometer
 - Pressure sensor
 - Microbridge gas sensor

Syllabus (3)

REFERENCES:

- Books
 1. G. Kovacs, *Micromachined Transducers Sourcebook*, McGraw-Hill, 1998.
 2. M. Madou, *Fundamentals of Microfabrication*, 2nd ed., CRC Press, 2002.
 3. N. Maluf, *An Introduction to Microelectromechanical Systems Engineering*, Artech House, 2000.
- Journals
 1. IEEE/ASME Journal of Microelectromechanical Systems (JMEMS)
 2. Sensors & Actuators
 3. IEEE Sensors Journal
 4. Journal of Micromechanics and Microengineering (JMM)
- Conferences
 1. IEEE MEMS conference
 2. Solid-State Sensors and Actuators workshop (Hilton Head)
 3. Transducers
 4. IEEE Sensors conference
 5. IEEE/LEOS Optical MEMS conference
 6. SPIE
- MEMS clearinghouse: <http://www.memsnet.org>

What is MEMS?

- ↗ Micro-electro-mechanical Systems (MEMS) ← US
 - Implies “electrical component or functionality”
 - Implies “mechanical component or functionality”
- ↗ Microsystems or Microsystems Technology (MST) ← Europe
 - “Very small systems”
 - “Systems made of small components”
 - No specific bias on functionality or manufacturing method
- ↗ Micromachines ← Japan
- ↗ In practice, MEMS applies to broader functional groups (electrical, mechanical, thermal, magnetic, fluidic, optical, chemical etc.)
 - **Making miniature sensors and actuators**
 - **Involving almost every discipline**
 - **Leveraging the existing IC technology**
 - **Enabling technology for many emerging markets**

What is MEMS? -- Applications

Biosensors
Micro-pumps, needles, ...
Lab-on-chip

Gyroscopes, Accelerometers
Micro propulsion systems
...

Ink-jet nozzles
Displays
Data storage
...

Chemical sensors
Micro fluidics
Mass spectroscopy
...



Micromirrors
All-optical switches
Microphones
Microspeakers
...

Inertial sensors
Gas sensors
Pressure, liquid level, ...

What is MEMS?

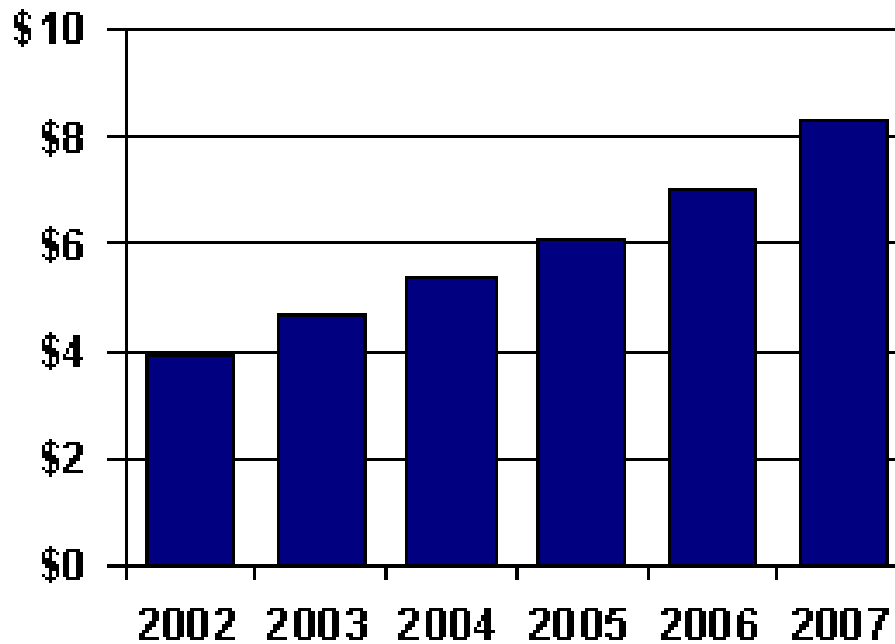
Some statistics

- The MEMS industry was a **\$2-5 billion** industry in 2000, expected to reach **\$8-15 billion** by 2004
- Today **1.6 MEMS devices** per person in the US
5 devices per person by 2004
- Over 70% of MEMS companies were founded between 1995 and 2001, with an average of 10 MEMS companies per year founded in the past three years.

Source: the MEMS Industry Group
(<http://www.memsindustrygroup.org>)

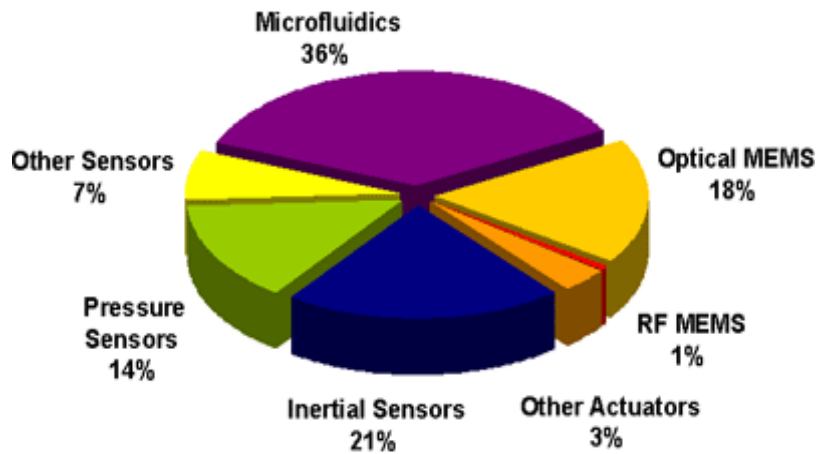
What is MEMS? -- Markets

**Worldwide Revenue Forecast for MEMS
2002-2007 (US \$ in Billions)**

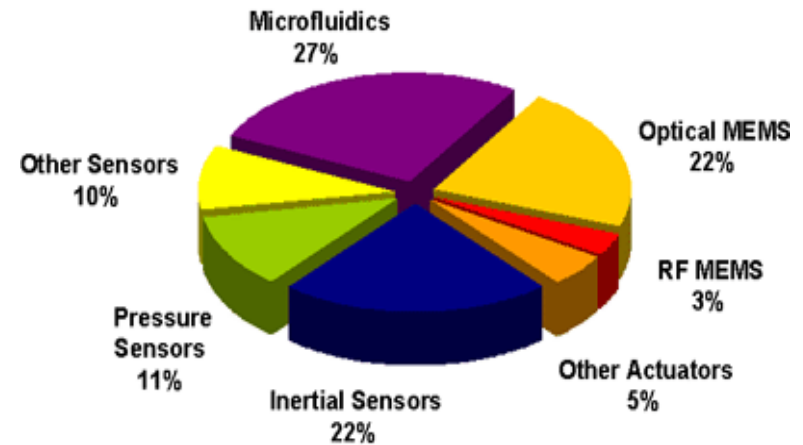


Source: <http://www.memsindustrygroup.org>

What is MEMS? -- Markets



2002



2007

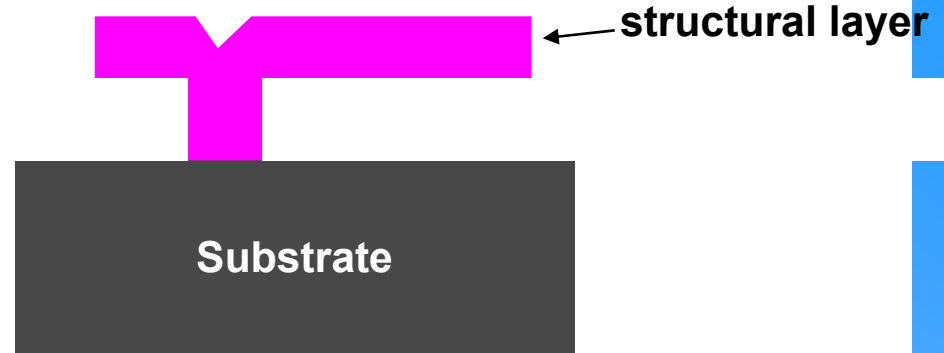
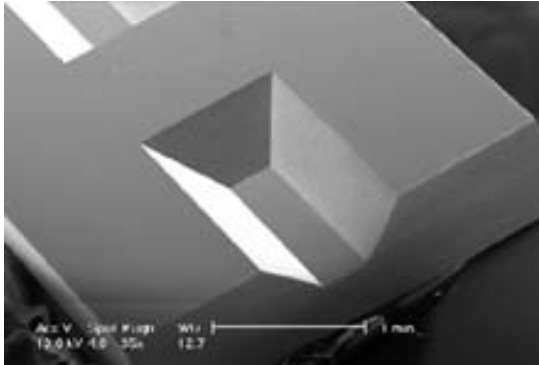
Source: <http://www.memsindustrygroup.org>

What is MEMS? -- Technology

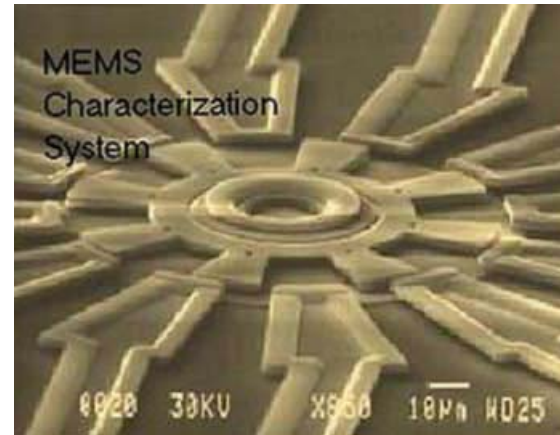
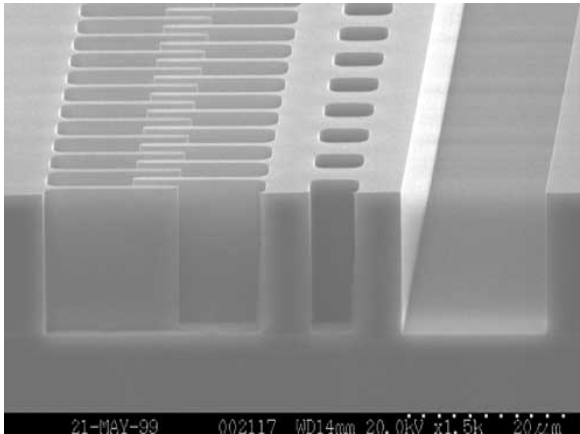
Bulk micromachining

Surface micromachining

Wet etch



DRIE



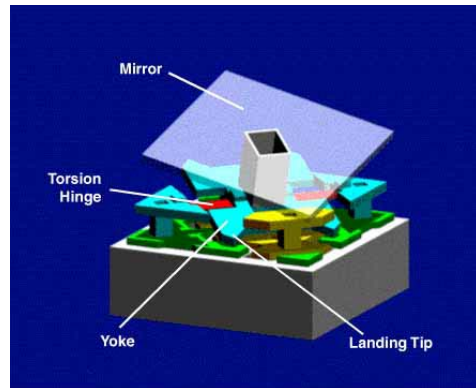
Micromotor

www.bco-technologies.com

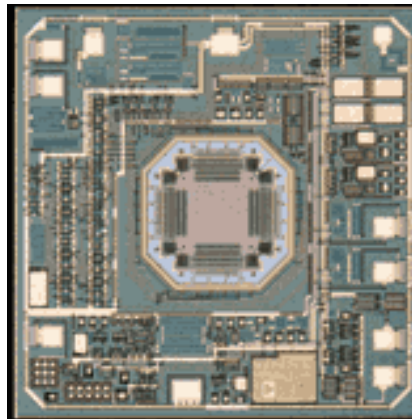
www.mit.edu

DRIE: deep reactive ion etch

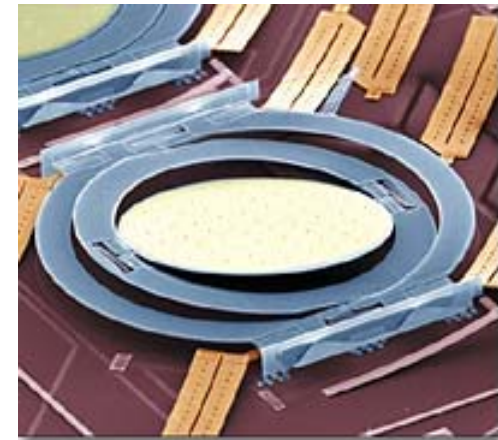
- Micromirror arrays for compact projectors
- Accelerometers for automotive
- Micromirrors for optical switching
- Many others



Texas Instruments'
Digital Micromirror Device



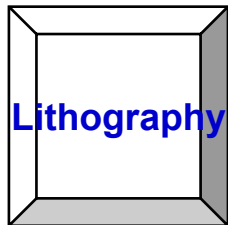
Analog Devices'
Accelerometer



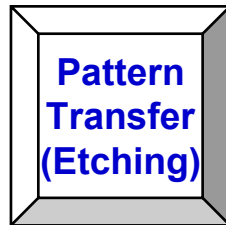
Lucent Technology's
2D micromirror for optical switch

Manufacturing--Methods

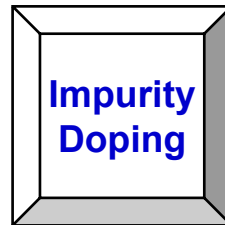
- Microfabrication + Micromachining
- Microfabrication
 - ↗ Borrowed from silicon integrated circuit fabrication
 - ↗ > 40 years of collective equipment and process experience
 - ↗ Key processes:



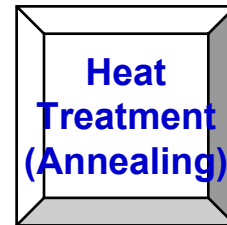
Contact
Projection



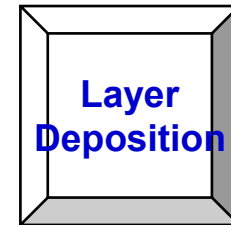
Wet
Dry
(Plasma,
RIE)



Ion implant
Solid source



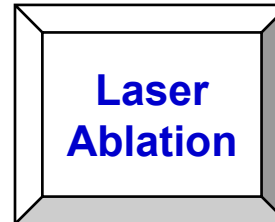
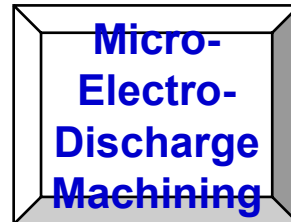
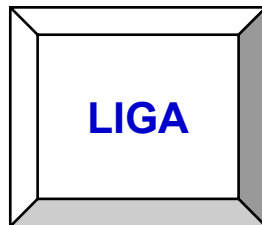
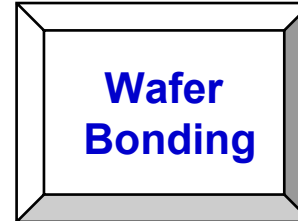
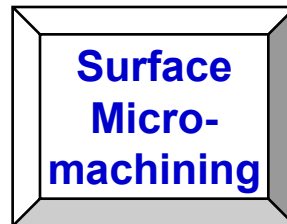
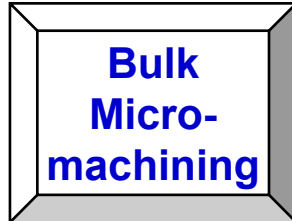
Furnace
RTA



Physical
Chemical

Manufacturing--Methods

- Microfabrication + Micromachining
- Micromachining
 - ↗ Specialized techniques for fabricating mechanical structures
 - ↗ May not be compatible with standard CMOS processing
 - ↗ Key processes:



Manufacturing--Materials

■ Microfabrication

- ↗ Single-crystalline silicon (starting wafer substrate) AND
- ↗ silicon dioxide, silicon nitride, polycrystalline silicon, aluminum, tungsten, copper

■ Micromachining

- ↗ Same + Micromachine-application specific materials
- ↗ Example: Lead zirconate titanate (PZT) for piezoelectric applications
- ↗ Example: Self-assembled monolayers for chemical sensing

Project

- The class will be divided into design teams. A design project will be assigned to each design team. Information given to each design team: Project Scope and Design Specifications.
- Literature review
- First order design
 - Design a process flow and mask set that produces a sensor with the desired specifications.
- Second order design
 - Design a more complete model that takes into account important factors that may affect the accuracy of the results.
- Control
 - Develop a control circuit for the sensor.
- Packaging
 - Develop a packaging solution
 - Analyze the effect of the package on the sensor specifications.

Project

■ Design deliverables:

- ↗ Literature review (Due September 27)
 - Literature review report with bibliography (one per design team)
- ↗ First order design review
 - First order design presentation (5 minutes per design team) (10/25)
 - First order design report (one per design team) (10/22)
 - Statement of individual contributions
 - Elements: cover page, table of contents, project scope, design specifications, literature review, first order design, and summary.
- ↗ Final design project summary
 - Final design project summary presentation (15 minutes per design team) (12/6, 12/8)
 - Final design project technical report (one per design team) (Due December 14)
 - Statement of individual contributions
 - Elements: cover page, table of contents, project scope, design specifications, literature review, first order design, second order design, control, packaging, and summary.

Survey

EEL5225 Principles of MEMS Transducers

Fall 2004 Semester

(3th Period, MWF, LAR 239)

Participant Survey:

Name: _____

Email Address: _____

Department: _____

Office: _____ Office phone: _____

Standing: Undergraduate Graduate Faculty/staff

Registered ? : (Yes/No) (Note: Students must be registered for
course)

If graduate student, indicate graduate advisor(s): _____ (or not
applicable) and current degree program (MS or PhD)

Please describe your area of interest in MEMS or sensors and actuators
including expectations for this course. (Please use the back of this
page if necessary.)