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ECE 6460 – Spring 2010
Microelectromechanical Devices

Instructor: Dr. Oliver Brand
Microelectronics Research Center, MiRC 219
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Office Hours: Monday, Wednesday and Thursday, 2-3PM

Class Times: Monday, Wednesday and Friday, 10:05-10:55 AM
Class Room: van Leer, C340

Contents: The graduate level course introduces fundamental concepts and tools needed for the design, simulation and analysis of microelectromechanical systems (MEMS). MEMS devices include at least electrical and mechanical components, and might interact with the mechanical, radiant, thermal, magnetic or chemical/biological signal domains. The course covers the mechanics of materials with focus on typical MEMS structures, such as cantilever beam and membranes, and the thermal transport in these structures. The theory of the most important transduction mechanisms, including piezoresistivity, piezoelectricity, electrostatics and thermoelectric effects is presented. In the final application-oriented part of the course, many examples of mechanical, thermal, magnetic, and chemical/biological transducers and their packaging are discussed. Students apply the concepts/tools covered in this course in a group design project.

Prerequisite: recommended is ECE6450 Intr. to Microelectronics Technology (or equivalent)

Textbook: S.D. Senturia, *Microsystem Design*, Kluwer 2001

Grading: **1 Design Project** (25%, performed in small teams) involving development of design idea, device simulation strategies, device implementation and fabrication process flow; the results are presented in class
2 Exams (15% each)
4 Homework Assignments (5% each)
1 Final Exam (25%)

Homework: Homework assignments will be collected at the end of the class on the day they are due. You are welcome, and even encouraged, to work together on the homework assignments, but do not just copy someone else's work.

Exams: There will be two exams/quizzes during the semester. The exams will consist of short questions, testing the overall understanding of the contents, rather than solving distinct problems. The quizzes will be closed book, closed notes. You may bring one US letter page (8.5 by 11 inches, front and back side) of notes and formulas.

Final Exam: The final exam will consist of a short question part and a problem part. The final exam will be open textbook (S.D. Senturia, Microsystem Design), open handouts.

Project: The goal of the design project is to cover a MEMS Design Cycle including system/device specifications, design idea, device/system modeling and device/system fabrication and packaging. The design project will be performed in groups of typically three students based on a particular case study. The device/system for the case study can be an already published/commercialized device or a new device idea that you might have (but not your own research topic!). A short 1-page proposal introducing your device (and an explanation why you have chosen it) is due by e-mail on February 26, 2010. The design projects will be presented during the final week of class. Each team will be given 15 minutes for the presentation and copies of the slides will be distributed in class.

Course Outline:

1. **Introduction**
   - History of Microsystem Technology; Overview on Commercial Products; Conferences and Publications; Literature
2. **The MEMS Development Cycle**
   Case Study: TI Digital Micromirror Device
   - Device Idea/Concept; Device Design: Modeling, Fabrication Process; Fabrication and Packaging; Testing
3. **Microsystem Fabrication**
   - Integrated Circuit Fabrication
   - Bulk/Surface Micromachining
4. **Microsystem Modeling**
   - Lumped Element Modeling
   - Finite Element Modeling
5. **Mechanical Analysis**
   - Theory of Elasticity
     - Stress & Strain
     - Elastic Constants
     - Thermal Expansion and Thin-Film Stress
     - Non-Idealities: Large Strain & Plasticity

- Mechanics of MEMS Structures
    - Beams: Torsion Bars, Axially Loaded Beams, Bending of Beams
    - Membranes and Plates
- Energy Methods
    - Principle of Virtual Work
    - Variational Methods
    - Rayleigh-Ritz Method

6. **Thermal Analysis**
    - Heat Transfer in MEMS Structures
        - Heat Conduction
        - Radiation
        - Heat Convection
        - Dissipative Processes
7. **Transduction Mechanisms**
    - Transducer Effects
    - Piezoresistivity
    - Piezoelectricity
    - Thermoelectric Effects
    - Electrostatics
    - Magnetoelectric Effects
8. **Transducer Examples**
    - Mechanical Transducers
        - Inertial Sensors (Accelerometer, Gyroscope)
        - Pressure Sensors
        - Flow Sensors
        - Force Sensors (SPM)
    - Chemical/Biological Transducers
        - Chemical and Biosensors
        - Needle Probes
    - Magnetic Transducers
        - Magnetic Field Sensors
        - Magnetic Actuators
    - Thermal Transducers
        - Thermometers
        - IR Sensors
    - Miscellaneous Transducers (depending on time and interest)
        - Microfluidics
        - Passive Components
        - Microresonators
        - Energy Harvesting Devices and Power Generators

ECE 6460 – Spring 2010 – Course Outline

Week	Date	Lecture Material	Homework
1	January 11 January 13 January 15	Chapter 1: Introduction Chapter 1: Introduction Chapter 2: MEMS Design Cycle	
2	January 18 January 20 January 22	*School Holiday (MLK Day)* Chapter 2: MEMS Design Cycle Chapter 3: Microsystem Fabrication	
3	January 25 January 27 January 29	*Movie: Silicon Run* Chapter 3: Microsystem Fabrication Chapter 3: Microsystem Fabrication	*MEMS 2010* *MEMS 2010* *MEMS 2010*
4	February 1 February 3 February 5	Chapter 3: Microsystem Fabrication Chapter 3: Microsystem Fabrication Chapter 3: Microsystem Fabrication	
5	February 8 February 10 February 12	Chapter 4: Microsystem Modeling Chapter 4: Microsystem Modeling Chapter 4: Microsystem Modeling	 Homework 1 due
6	February 15 February 17 February 19	Chapter 4: Microsystem Modeling Chapter 4: Microsystem Modeling **Exam 1**	
7	February 22 February 24 February 26	Chapter 4: Microsystem Modeling Chapter 4: Microsystem Modeling Chapter 5: Mechanical Analysis	 *Project Outline due*
8	March 1 March 3 March 5	Chapter 5: Mechanical Analysis Chapter 5: Mechanical Analysis Chapter 5: Mechanical Analysis	
9	March 8 March 10 March 12	Chapter 5: Mechanical Analysis Chapter 5: Mechanical Analysis Chapter 5: Mechanical Analysis	 Homework 2 due
10	March 15 March 17 March 19	Chapter 6: Thermal Analysis Chapter 6: Thermal Analysis Chapter 6: Thermal Analysis	
11	*March 22-26*	*Spring Break*	
12	March 29 March 31 April 2	Chapter 7: Transduction Mechanisms Chapter 7: Transduction Mechanisms Chapter 7: Transduction Mechanisms	 Homework 3 due
13	April 5 April 7 April 9	Chapter 7: Transduction Mechanisms Chapter 7: Transduction Mechanisms **Exam 2**	
14	April 12 April 14 April 16	Chapter 7: Transduction Mechanisms Chapter 7: Transduction Mechanisms Chapter 8: Transducer Examples	
15	April 19 April 21 April 23	Chapter 8: Transducer Examples Chapter 8: Transducer Examples Chapter 8: Transducer Examples	 Homework 4 due
16	April 26 April 28 April 30	Chapter 8: Transducer Examples Chapter 8: Transducer Examples Chapter 8: Transducer Examples	
	May 5	11:30am – 2:20pm (tentative schedule)	Final Exam