Course Syllabus

VM553

Microelectromechanical Systems

Summer 2021

Course Description:

Micro **E**lectro **M**echanical **S**ystems (MEMS) are miniature devices (with micron size tolerances) that are created using various techniques including many similar to those used to manufacture integrated circuits, and are capable of performing many tasks and functions that involve mechanical, electrical, optical, chemical, bio, fluidic, and other types of signals. MEMS and Integrated Microsystems are increasingly finding applications in many areas including automotive, health care, industrial processing, environmental monitoring, biomedical systems, chemical analysis, energy sources, telecommunication, aerospace systems, consumer appliances, and many others.

This course introduces students to this rapidly emerging, multi-disciplinary, and exciting field. It will teach fundamentals of micromachining and microfabrication techniques, including planar thin-film process technologies, photolithographic techniques, deposition and etching techniques, and the other technologies that are central to MEMS fabrication. A designer of MEMS requires knowledge and expertise across several different disciplines. Therefore, this course will pay special attention to teaching of fundamentals necessary for the design and analysis of devices and systems in mechanical, electrical, fluidic, and thermal energy/signal domains, and will teach basic techniques for multi-domain analysis (e.g., electromechanical, electrothermal). Fundamentals of sensing and transduction mechanisms (i.e. conversion of non-electronic signals to electronic signals), including capacitive and piezoresistive techniques, and design and analysis of micromachined miniature sensors and actuators using these techniques will be covered. Many examples of existing devices and their applications will be reviewed.

Instructor:

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Office hour: Tuesday and Thursday 2:00 pm – 3:00 pm (individual meetings available by appointments)

COURSE OBJECTIVES:

1. To introduce students the concept of MEMS;
2. To teach students the properties of materials used in microfabricated MEMS devices;
3. To teach students the complete micromachining process for fabricating MEMS devices;
4. To teach students analysis and design of capacitive sensors and actuators;
5. To teach students analysis and design of piezoresistive MEMS sensors including pressure sensors and accelerometers;
6. To teach students analysis and design of thermal actuated MEMS sensors;
7. To expose students the rapidly emerging MEMS-related areas such as bioMEMS, microfluidics, and RF MEMS and so on.

COURSE OUTCOMES:

1. Able to select suitable MEMS materials and design an appropriate microfabrication procedure given a MEMS device structure;
2. Able to design and analyze the dynamic motion of movable components in a MEMS device;
3. Able to understand and design capacitive transducers;
4. Able to understand and design piezoresistive sensors;
5. Able to understand and design electro-thermal actuators and sensors;
6. Able to understand and design piezoelectric transducers and MEMS resonators;
7. Able to follow the state-of-the-art scientific publications and industrial products in the field of MEMS.

Textbook (Author, Book Title, Publisher, Publication Year, ISBN**):**

There is no formal required textbook for this course. Lecture notes will be posted online. Here is the recommended textbook for reference (One copy is available in JI Office 315):

- Chang Liu, *Foundations of MEMS (2nd Edition)*, Pearson/Prentice Hall, 2010, 978-0-13-249736-7.

Because this course teaches a field with current research activities worldwide and involving rapid development, additional reading is an indispensable part, which shall include the most recent publications in relevant conferences and journals. A project involving searching and reading research papers will be assigned. Below are representative conferences and journals in the research field of MEMS:

- Digest of Technical Papers, International Conference on Solid-State Sensors and Actuators (Transducers), held every other year.
- Digest of Technical Papers, Solid-State Sensors and Actuators Workshop, held every other year in Hilton Head, South Carolina, USA.
- Digest of Technical Papers, IEEE International Electron Devices Meetings (IEDM), held every year.
- Proceedings, IEEE International Conference on Micro Electro Mechanical Systems (MEMS).
- IEEE/ASME Journal of Micro Electro Mechanical Systems (JMEMS), published by the Institute for Electrical and Electronics Engineers. See IEEE website at www.ieee.org
- Sensors and Actuators Journal [A (Physical) and B (Chemical)], published by Elsevier Publishing, https://www.journals.elsevier.com/sensors-and-actuators-a-physical and https://www.journals.elsevier.com/sensors-and-actuators-b-chemical
- Journal of Micromechanics and Microengineering (JM&M), published by British Institute of Physics), https://iopscience.iop.org/journal/0960-1317

Course Prerequisites:

This course is an introductory course designed for those students who are not familiar with MEMS, microfabrication technologies, integrated circuits, or non-electrical devices and systems. Therefore, the course pre-requisites are selected to allow students from many engineering or science disciplines,

including mechanical, electrical, chemical, aerospace, biomedical, and materials engineering to take the course. The lectures will present materials to help students with various backgrounds to learn.

The following academic background is strongly recommended for this course: Vv215, Ve215, Vp240, and junior or senior or graduate standing.

Course Website:

https://umjicanvas.com/courses/2185

Grading Policy (Assignments %, Project, Exams, etc.):

Homework	25%
Midterm Exam	25%
Presentations (Course Project)	15%
Final Exam	30%
Class participation	5%

Honor Code Policy:

All students enrolled in this course are presumed to be decent and honorable, and all students are bound by the Honor Code of the UM-SJTU Joint Institute (visit http://umji.sjtu.edu.cn/honorcode for more details). You may not seek to gain an unfair advantage over your fellow students; you may not consult, look at, or possess the unpublished work of another without their permission; and you must appropriately acknowledge your use of another's work. You may form a small group to discuss together on homework problems but what you submit should reflect your own thinking. Direct copying of another student's work, even with paraphrasing, will be resulting in possible Honor Code violations.

Teaching Schedule:

Week	NO.	lectures and Exams	Comments

1	1	Administrative Information, Introduction and Motivation, Examples of MEMS devices	
	2	Review semiconductor electrical properties and standard semiconductor processing technologies	
2	3	Silicon micromachining and MEMS process technologies	
	4	Silicon micromachining and MEMS process technologies	
3	5	Silicon micromachining and MEMS process technologies	
	6	Material properties	
4	7	Review of mechanical structures, elasticity, dynamics	
	8	Review of mechanical structures, elasticity, dynamics	
5	9	Capacitive sensors	
	10	Capacitive sensors	
6	11	Holiday for Dragon Boat Festival	No class
	12	Review and midterm exam preparation	
7	13	Midterm exam	
	14	Capacitive actuators	
8	15	Capacitive actuators	
	16	Piezoresistive sensors	
9	17	Piezoresistive sensors	
	18	Electro-thermal MEMS transducers	
10	19	Electro-thermal MEMS transducers	
	20	Brief introduction of novel MEMS devices: radio-frequency (RF) MEMS	
11	21	Brief introduction of novel MEMS devices: soft/polymer MEMS, microfluidics, bioMEMS	
	22	Brief introduction of novel MEMS devices: optical MEMS	
12	23	Group project presentations - Session #1	
	24	Group project presentations - Session #2	
13	25	Final exam	
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