Title: Introduction to Micro and Nano Electro Mechanical Systems (MEMS/NEMS)

Credits: 4 (LCT:4)

WSU Catalog Description: Prereq. or coreq: instructor’s consent. General and highly specialized micro/nanofabrication techniques; basic sensing and actuating mechanisms (piezoresistive, piezoelectric, capacitive, electrostatic, thermal pneumatic, etc); and design and operation of various MEMS/NEMS devices for automotive and biomedical applications (T)

Coordinator: Yong Xu, Associate Professor of Electrical and Computer Engineering

Instructor: Yong Xu
Office Hours: Tuesday 1:30pm – 3:30pm (or by appointment).
Office Location: 3131 Engineering
Phone: 313-577-3850 Email: yxu@ece.eng.wayne.edu
Course Meeting Time: T Th 3:30pm – 5:20 pm
Course Meeting Location: 0211 MANO

Goals: To give students fundamental knowledge of MEMS/NEMS. To prepare students for advanced researches/education involving micro/nano devices

Textbook: No textbook is required for this course. Class notes and selected papers will be distributed in class.

References:
- Books:
  - M. Madou, Fundamentals of Microfabrication, CRC Press
  - Chang Liu, Foundations of MEMS (Prentice Hall, 2005).
- Journals:
  - IEEE/ASME Journal of Microelectromechanical Systems
  - Sensors and Actuators
  - Journal of Micromechanics and microengineering
- Conferences proceedings:
  - Solid-State Sensor and Actuator Workshop (Hilton Head) (even year)
  - IEEE Micro Electro Mechanical Systems Workshop (MEMS) (annually)
  - Int. Conf. on Solid-State Sensors and Actuators (Transducers) (odd year)
  - Micro Total Analysis Systems (μTAS)
- Internet
  - General search engine: http://www.google.com
  - MEMS clearinghouse: http://www.memsnet.org (particular good for its discussion group)
  - News: http://www.smalltimes.com (MEMS and nanotechnology)
  - Websites of the MEMS research groups at universities
  - Websites of MEMS companies and research institutions (e.g., Sandia National Lab)
- Patents
- Thesis

Learning Objectives: At the end of this course, students will be able to:
1. describe processes and underlying physics of fundamental micro/nanofabrication technologies.
2. explain the operating principles of basic sensing and actuating mechanisms.
3. explain the operating principles of some fundamental MEMS/NEMS devices.
4. design fundamental MEMS/NEMS devices such as cantilevers, pressure sensors, accelerometers, etc.
5. write technical report and present it effectively.

Prerequisites: This class covers a broad set of topics in multi-disciplines but does not have specific prerequisites. Senior undergraduate and graduate students, who are interested in MEMS, from Electrical and Computer Engineering, Mechanical Engineering, Material Science Engineering, Chemistry, Chemical Engineering, Civil Engineering, Biology, Bioengineering, Biomedical Engineering, and other departments, are all welcome to register. This course is also open to seniors.

Course Structure: The class meets twice a week, two hours each for total 4 credit hours.

Computer Resources: Word, Powerpoint, math software, finite element analysis software (optional)

Laboratory Resources: N/A.

Laboratory Policy: N/A

Grading:
- Attendance and class discussion: 20%
- Homework: 20%
- Class project (including oral presentation): 60%

For graduates For undergraduates:
A: 92~100 A: 90~100
A-: 86~91 A-: 84~89
B+:82~85 B+:80~83
B: 76~81 B: 75~79
B-:70~75 B-:70~74
C: 60~69 C: 60~69
F: <60 F: <60

Attendance: Students are expected to attend all lectures

Topics and tentative course schedule
- Microfabrication and related topics (week 1-6):
  1. Photolithography
  2. Bulk and surface micromachining, plasma dry etching, gas-phase etching, wafer bonding, LIGA, LIGA-like process, etc.
  3. Double-side alignment, corner compensation, stiction and anti-stiction methods, sealing methods, etc.
  4. Mechanical properties of thin films: residual stress, stress gradient, Young's modulus, fracture strain, etc.
  5. MEMS materials: polysilicon, low-stress silicon nitride, LTO, PSG, metals and polymers etc.
  6. Thin film deposition: chemical vapor deposition (CVD), evaporation, and sputtering, etc.
  7. Nanofabrication.
- Mechanical theories and mechanical MEMS (week 7-11)
  1. Mechanical dynamics, beam theories, etc.
  2. Piezoresistive sensing, capacitive sensing, tunneling sensing, resonant sensing.
  3. Accelerometers, pressure sensors, microphones, tactile sensors.
  4. Piezoelectricity, electrostatic actuation.
- Thermal MEMS (week 12)
1. Fundamentals of heat transfer.
2. Temperature sensors, thermal flow sensors, and thermal gas sensors.
3. Thermal actuation: thermal bimorph, thermal pneumatic, shape memory alloy, etc.
4. Uncooled IR imagers, Golay cells.
- Microfluidics and bioMEMS (week 13-14)
  1. Channels, mixers, pumps, valves, etc (basic building blocks of Lab-on-a-chip)
  2. DNA chips, PCR, etc.
- Invited MEMS/NEMS seminars (TBD)

Note: there might be some overlaps between different topics

Outcome Coverage:
(a) an ability to apply math, science and engineering knowledge. The lectures, homework, especially the class project all require direct application of mathematics, scientific, and engineering knowledge.
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability; Design of MEMS/NEMS devices is an essential component of this course. In the lecture, many design examples will be discussed, considering realistic constraints. This capability is especially covered in the class project, in which students are required to design a MEMS/NEMS device for practical applications.
(d) an ability to function on multi-disciplinary teams. MEMS/NEMS is multidisciplinary by its nature. The topics of this course cover electrical engineering, mechanical engineering, materials science, chemistry, biology, optics, etc. The students are encouraged to form multi-disciplinary teams to work on the class projects.
(e) an ability to identify, formulate and solve engineering problems. The class project requires the students to identify, formulate and solve engineering problems.
(g) an ability to communicate effectively. At the end of this course, the students are required to present their projects in front of the whole class. The ability to communicate effectively is essential.
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. The successful finish of this course, especially the class project, requires the ability to use the techniques, skills, and modern engineering tools.

Withdraw policy:

- Students must drop classes via the Web by logging into Pipeline (http://pipeline.wayne.edu). If a student has a hold and needs help dropping a class then they should send an e-mail request from their WSU e-mail account to registration@wayne.edu with the appropriate course information. Students may drop a class (for fifteen week classes) through the end of the fourth week of class. Classes that are dropped do not appear on the transcript.

- Beginning the fifth week of class students are no longer allowed to drop but must withdraw from classes via Pipeline. It is the student’s responsibility to request the withdrawal. Beginning Fall 2011, the withdrawal period for full-term classes ends at the end of the tenth week of the term. See the Academic Calendar for specific information on when the withdrawal period ends:

  http://reg.wayne.edu/students/calendar.php

Makeup Exam and Makeup Assignment Policy: No late assignments will be accepted.

Academic Integrity Policy:
Wayne State University is committed to the highest standards of academic integrity. You are expected to conduct yourself in accordance with these standards. To the extent that this course relies on project reports and independent research papers, be especially aware of proper attribution and citation standards to avoid even the appearance of plagiarism.
Per the Student Code of Conduct, any violations of academic integrity will be handled via a combination of downgrading (up to and including failing the course) and prosecution via the Dean of Students and College of Engineering’s Judicial Officer, which can result in permanent transcript notations or even expulsion from the University.

Be sure you are familiar with the material on the following links:

- [http://www.doso.wayne.edu/student-conduct/Student_Code_Conduct.html](http://www.doso.wayne.edu/student-conduct/Student_Code_Conduct.html)
- [http://www.trc.wayne.edu/node/48](http://www.trc.wayne.edu/node/48)

**Student Disability Services**: If you have a documented disability that requires accommodations, you will need to register with Student Disability Services for coordination of your academic accommodations. The Student Disability Services (SDS) office is located at 1600 David Adamany Undergraduate Library in the Student Academic Success Services department. SDS telephone number is 313-577-1851 or 313-577-3365 (TTY: telecommunication device for the deaf; phone for hearing impaired students only). Once you have your accommodations in place, I will be glad to meet with you privately during my office hours to discuss your special needs. Student Disability Services’ mission is to assist the university in creating an accessible community where students with disabilities have an equal opportunity to fully participate in their educational experience at Wayne State University.

**Prepared By**: Yong Xu, Associate Professor of Electrical and Computer Engineering

**Last Revised**: Jan. 2, 2011