SYLLABUS
ENME 476/808K, Microelectromechanical Systems (MEMS)
Spring 2016

Course Description
In this introductory MEMS class, we cover the fundamental basis of microsystems technology. Microelectromechanical devices (MEMS), such as actuators, pressure sensors, and optomechanical assemblies, require knowledge of a broad range of disciplines, from microfabrication to chemistry and solid state device physics. These topics are covered in this course, with a strong emphasis on fabrication. The class includes a mandatory laboratory component. The undergraduate version of this course is aimed at the student who is interested in gaining an understanding of how micromachines are designed and fabricated, and the graduate version is aimed at students interested in pursuing MEMS in their research or careers.

476 vs. 808K
Students (both undergrad and grad) can register for either 476 or 808K, as they wish. 808K students will do additional work and may have additional problems on quizzes or exams.

Lecturer
Dr. Elisabeth Smela
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email: smela@umd.edu
office hours: tentatively 11-12 pm Tuesdays or by appointment

Laboratory Instructors
Tom Loughran, Jon Hummel, John Abrahams
Tom: tcl@umd.edu, x5-3642
Jon: jhummel1@umd.edu, x5-5017
John: jabrah@umd.edu, x5-5017
Alternate contact:
Jim O’Connor, clean room manager in the Kim Building
joconnor@umd.edu, x5-x5018

Textbook
This book has recently gone out of print. The author’s permission has been obtained to use the first two chapters in the course, to be distributed on paper but not electronically.

Class Web Site
Communication between instructor and students outside the classroom will be primarily through Canvas. Students are expected to check for announcements and assignments regularly.

INTRODUCTION
This course is the introductory MEMS offering at the University of Maryland. It will prepare you for more advanced study, including courses such as ENME 602, MEMS Device Physics and Design; ENME 808U, Microfluidics and BioMEMS, and ENEE719R Advanced Topics in Microelectronics: Design and Fabrication of Micro-Electro-Mechanical Systems, or graduate work in MEMS.

SCHEDULE
The detailed class schedule will be posted online. *It is subject to update and change as we proceed through the semester.* When the schedule is changed, an announcement will be posted.

LECTURES
The book for the course, Kovacs, is not a textbook but a handbook, and it is an excellent, valuable resource for those students who continue in this field. I will use classroom time to supplement the material in the book and answer any questions you have about the reading. Lectures will cover aspects of what you’ve read in more depth, as well as cover material that is not included in the book. Skills in life-long independent learning are among the objectives of this course; students are expected to have done the assigned reading for each lecture and should be prepared to discuss the material in class. Active participation by every student is expected.

Lectures will be presented using Powerpoint and the blackboard. The lecture notes will be posted prior to the lecture if you wish to consult or print them. We may on occasion have guest speakers.

Lectures will cover microfabrication techniques, fabrication sequences, mask design, and semiconductor device physics.

*Introduction to MEMS*  
transducers, markets, information resources

*MEMS Fabrication Processes and Materials*  
bulk micromachining, wet etching, dry etching, surface micromachining, sacrificial layers, film deposition, bonding, sacrificial layers, soft lithography and other non-traditional micromachining, self-assembled monolayers

*Introduction to Solid State Devices*  
crystal lattices, basic atomic physics, band structure, semiconductors, band structure, doping, p-n junctions, transistors

We may mix device physics and MEMS in the lectures. Semiconductor physics is covered because MEMS device operation cannot be understood properly without this knowledge. Everything written in this field presumes that the reader has this background.
LABORATORY
The lab is worth a significant portion of the course grade. The lab will give you the opportunity to get hands-on experience with basic processing steps. The class has several 3-hour slots a week. You will thus have one lab period every one or two weeks in groups of no more than five, with 4-5 labs total during the semester. Because of the constraint on the lab time, class enrollment is limited.

You are responsible for showing up at your lab slot on time. Because the clean room is in continuous use by a substantial number of courses this semester, it will be impossible to hold special sessions to accommodate students who forget their lab time. If you need to switch with someone else, it’s fine for you to arrange to do so.

The labs will be held in the Kim building clean room teaching lab. The lab topics are as follows. Further information will be posted on Blackboard.

lab 1
safety, MSDSs, photolithography (resist spinning, alignment, exposure, development)

lab 2
metal etching, stripping of resist, alignment to a previous pattern

lab 3
wet etching of oxide and KOH etching of Si

lab 4
device testing

lab 5
extra time if needed

Clean room time, equipment, and chemicals are expensive. Therefore, participation in the laboratory is a privilege. Inappropriate or dangerous behavior in the clean room will result in dismissal from the lab for the rest of the semester, which will impact your grade.

Laboratory homework will be assigned and graded. These assignments will be described in a separate document. You are responsible for knowing and understanding what happened in every lab, and will therefore be required to take and hand in notes. The clean room will provide clean room paper for this.

REPORT
The 476 version of the course will include a written report and presentation. Report assignments will be described in detail in a separate document.

PROJECT
The 808K version of the course will include a design project with an assigned report and presentation. Projects will be done individually, with the option under some circumstances to work in pairs. The project assignments will be described in detail in a separate document.
HOMEWORK
Homework problems will be assigned weekly. Students should view homework as a learning experience. The purpose is not to hand something in, but to use the exercises to understand and gain familiarity with the material.

As a courtesy to the professor, solutions should be written neatly. Work that is difficult to read may be returned without being graded at the discretion of the instructor. Show all work, or full credit cannot be given.

LATE WORK
In exceptional circumstances (illness, university business, religious observances) extensions may be granted for assignments. However, all extensions must be approved by the instructor BEFORE the due date.

TESTS AND FINAL EXAM
There will be in-class quizzes/exams throughout the semester and a final. An equation sheet may be attached to the exam a sheet; if so it will be posted before the exam so you know what’s on it.

UNIVERSITY EXAM POLICIES
Make-up tests and exams will not be given unless a student can present evidence that an absence was for a University-accepted reason, such as serious illness, a death in the immediate family, religious observance, or participation in University activities at the request of University authorities. Please contact me before an anticipated test or exam absence, if at all possible. If you have a documented disability and wish to discuss academic accommodations with me, contact me as soon as possible at the beginning of the semester.

The following university rules govern all in-class examinations. A breach of any of the rules constitutes a "disruption of class," a disciplinary offense (Code of Student Conduct, section 9.m.), or may serve as the basis of an allegation of academic dishonesty.
1. Students arriving late for an examination may not unreasonably disrupt the examination room.
2. Students must leave all unauthorized materials (e.g., books, notes, calculators) with the proctor before being seated.
3. Where seating arrangements are established by proctors, student must conform to these arrangements.
4. Students may not return to an examination room after leaving, unless permission to do so has been granted by the proctor prior to the student's departure.
5. Students must cease conversation prior to the passing out of examination papers and maintain silence during the entire examination period.
6. Students must place examination papers face down on the writing desk until the examination is officially begun by the proctor.
7. Students must keep examination papers flat on the writing desk at all times.
8. Students at an examination must be prepared to show current University identification.

ATTENDANCE & PARTICIPATION
Attendance and active participation are required. Students are expected to attend the entirety of each class and to draw from the assigned homework material in class participation. Students are expected to be in class on time – coming late interrupts the class and causes you to miss important announcements.

The format of the course will be lecture and discussion. Classroom time offers you the opportunity to ask questions about the reading or other topics. Lectures will deal with the general subject matter of the textbook but will also include material not in the text. You will be expected to discuss the materials that have been covered in class.

**ASSESSMENT**
The course grade will be calculated as follows. Point breakdowns for each of these major components will be posted online.

<table>
<thead>
<tr>
<th>Component</th>
<th>476</th>
<th>808K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participation</td>
<td>10%</td>
<td>5%</td>
</tr>
<tr>
<td>Homework</td>
<td>15%</td>
<td>15%</td>
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<tr>
<td>Labs</td>
<td>30%</td>
<td>25%</td>
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<tr>
<td>Report</td>
<td>10%</td>
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<tr>
<td>Project</td>
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<tr>
<td>Tests</td>
<td>20%</td>
<td>20%</td>
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<tr>
<td>Final Exam</td>
<td>15%</td>
<td>15%</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td>100%</td>
<td>100%</td>
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Work that is handed in late without pre-approval by the instructor or a university-accepted excuse will not receive credit and will not be graded. If you have an emergency that will cause you to miss a deadline, contact me. Tests and exams can only be rescheduled for university-accepted reasons.

**COURSE OBJECTIVES**
The goals of the course are for you to:
1) know what types of MEMS devices there are and when it makes sense to fabricate one;
2) understand the micromachining techniques, including what they are, when and how to use them, and what needs to be considered when using them;
3) know the materials that can be used in MEMS, what they can be used for, and how they can be deposited and etched;
4) demonstrate proficiency in designing process sequences;
5) understand the basic concepts of semiconductor device physics;
6) pay attention to the important things in the laboratory and follow good lab practice;
7) be able to perform basic photolithography and patterning steps;
8) develop life-long learning skills, including learning how to find and learn to read the MEMS literature (journal articles, conference proceedings, course book); and
9) gain experience with applying the engineering method.

Articulate the objective to be achieved.
Generate a candidate plan for achieving the objective.
Evaluate candidate plans in light of relevant circumstances and decide whether it is suited to achieve the stated objective(s).

**LEARNING OUTCOMES**

This course addresses the following departmental student learning outcome objectives.

(a) An ability to apply knowledge of mathematics, science, and engineering.
(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.
(e) An ability to identify, formulate, and solve engineering problems.
(g) An ability to communicate effectively.
(i) A recognition of the need for, and an ability to engage in life-long learning.
(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

**EFFECTIVE NOTE-TAKING**

A substantial amount of material will be presented to you orally in this class. You will be responsible for all the material discussed in class. In order to get the most out of the course, I suggest following these note-taking strategies.

- Review the lecture notes before the class at which they will be discussed. If possible, print them and bring them to class.
- Take notes of things that are said and discussed, as well as what’s written on the board. If I’m talking about something, then it is generally important.
- It is a good habit every evening after class, or at the latest the next day, to recopy your notes into a neat, organized format. Use this time to review the material and make sure that you understand it. This is a key step in the learning process and will aid you in studying for exams.
- Ask, either privately, during office hours, or during class time, for clarification of those points that are not clear to you or that you didn’t catch. Takes notes of the explanation, and modify your class notes accordingly.

**ACADEMIC INTEGRITY**

The University of Maryland, College Park has a nationally recognized code of Academic Integrity, administered by the Student Honor Council. This Code sets standards for academic integrity at Maryland for all undergraduates and graduate students. As a student you are responsible for upholding these standards for this course. It is very important for you to be aware of the consequences of cheating, fabrication, facilitation, and plagiarism. For more information, please visit [http://www.shc.umd.edu/](http://www.shc.umd.edu/).

Academic integrity is a foundation for learning. The University has approved a Code of Academic Integrity available on the web at [http://www.testudo.umd.edu/soc/dishonesty.html](http://www.testudo.umd.edu/soc/dishonesty.html). The Code prohibits students from cheating on exams, plagiarizing papers, forging signatures, etc. The Code is administered by a Student Honor Council, which strives to promote a community of trust on the College Park campus. Allegations of academic dishonesty can be reported directly to the Honor Council (314-8206) by any member of the campus community.
I strongly encouraged you to discuss the course material with each other to help you understand and learn it. However, everything you turn in must be your own work. I expect that you are capable of distinguishing between helping others and cheating. You should never look at another student's answers, either from this class or any previous classes, nor should you ever look at a solution set from a previous year. Likewise, you should never give anyone else the answers to questions on homework or exams. You should also never copy a process sequence from anywhere, not even from the textbook. If you would like clarification, please see me.

The University Senate requires that students sign this statement if it is included on an exam or assignment:

“I pledge on my honor that I have not given or received any unauthorized assistance on this examination (or assignment).”

LEARNING ASSISTANCE SERVICE
If you experience difficulty in keeping up with the academic demands of this course, you may contact the Learning Assistance Service, 2202 Shoemaker Building, 301-314-7693. Their educational counselors can help with time management, reading, math learning skills, note-taking, and exam preparation skills. All their services are free to UMD students.