BME-451L: Fundamentals of Biomedical Microdevices Fall 2022

Instructors Ellis Meng, ellis.meng@usc.edu
MCB 471
Office hours TBD
(213) 740-6952

TA TBD
Office hours TBA, DRB-156

Lecture TTh 9:30a-10:50a, DRB 351

Lab Times TBD (110-minute session/week), BHE B8 and DRB 351, location will be specified

Corequisites EE 202L

Textbook Biomedical Microsystems (E. Meng), CRC Press, 2010. ISBN: 9781420051223
Additional reading material may also be posted to course website or handed out in class.

Class Website https://blackboard.usc.edu (follow link to BME 451)
Be sure to change your email to the one you use most frequently as we will send out email messages during the semester using your Blackboard listed email address

Course Learning Outcomes

The main goal is to introduce students to the diverse and highly interdisciplinary field of biomedical microdevices with an emphasis on biomedical microelectromechanical systems (bioMEMS) and microtechnologies. Students will learn the building blocks of these devices, how they are constructed, and the principles governing their operation and performance. Emphasis is placed on learning the fundamental principles of these microdevices so that students can appreciate the technical challenges and opportunities that biomedical microdevices brings to life and medical sciences. Finally, students will be able to engage in hands-on activities featuring fabrication and design of biomedical microdevices.

Learning Objectives and relation to BME Program Outcomes[1]

After successfully completing this course, you should be able to:

1. Integrate knowledge of life and medical science learned in previous courses to create implementable solutions to microengineering problems at the interface of engineering, medicine, and biology and independently acquire through new reading, practice exercises, and self-initiated research technical knowledge related to the course content and projects, including emerging applications of biomedical microdevices (outcomes a, f, h, i, j, k)
2. Select appropriate materials for the construction of biomedical microdevices (outcomes a, c, f, k)
3. Develop and design simple layouts and fabrication process flows for created biomedical microdevices (outcomes c, e, f, k)
4. Construct simple microfluidic systems and perform experiments using these devices (outcome b, e, k)
5. Describe different biosensing mechanisms and choose the appropriate method for a particular application (outcomes a, c, k)
6. Function effectively as a part of a group of student engineers working on a multi-week project & document in writing and orally exercises and projects performed individually and as part of a team of student engineers (outcomes d, f, g, j, k)

Relationship of Course to Program Outcomes[1]

This course contributes strongly to Program Outcomes a, c, d, e, g, h, i, and k, and moderately to Program Outcomes b, f, and j.

Course Topics

The course plan below reflects the course goal and objectives. Note that there are more topics than can be covered and special topics are rotated from year to year such that the latter part will rotate through topics (starting with cell manipulation). The full range of topics include:

Introduction and Overview: Why miniaturization? Dimensions and scaling challenges in bioMEMS
BioMEMS Materials: From silicon to polymers, the need for biocompatibility
Microfabrication for BioMEMS:

Introduction to micropatterning, micromachining, and micromolding with consideration given to device/system design

Surface and bulk micromachining, etching and thin film processes
System Integration: Bonding, assembly, packaging, and other microfabrication techniques
Biosignal Transduction Mechanisms:
Challenges of biosensing, principles: mechanical, thermal, optical, acoustic, electrochemical, conductometric, potentiometric, amperometric
BioSensors: Examples and applications
Cell Manipulation: Governing forces and manipulation strategies
Microfluidics: Introduction, properties of biological fluids in microchannels, devices
Lab-on-a-Chip: Microanalytical systems in chemistry and biology
MEMS Implants and Bioelectric Interfaces: Implantable microelectrodes, shunts, etc.
Microengineering in Biotechnology: PCR, microarray technology, optical detection
Biomedical Microdevice Research at USC: Guest speakers and instructors research
What's next? Frontiers in BioMEMS
Nanolithography, biomimetic nanodevices, nanotubes
Commercialized devices, in depth look at specific topics in biomedical microdevices

Course Schedule

The weekly breakdown for the course is below:

Wk	Class	Agenda	Assignments	Labs
1	1	Course Introduction	Milestone 1 Teams out	Lab 1: Lab safety
	2	Introduction Scaling I	HW1 out	
2	3	Scaling II Materials I		Lab 2: Silicon cleaving
	4	Materials II Microfabrication I - lithography	Milestone 1 Teams due	
3	5	Cleanroom introduction Silicon Run video	Milestone 2 Topics out	Lab 3: Mask layout and design
	6	Microfabrication II – Additive processes	HW1 due HW2 out	
4	7	Microfabrication III – Additive processes	Milestone 2 Topics due Milestone 3 Outline & Refs out	Lab 4: Masking techniques
	8	Microfabrication IV – Subtractive processes		
5	9	Microfabrication V - Subtractive		Lab 5: Wet etching
	10	Cleanroom tour MEMS video	HW2 due HW3 out	
6	11	Microfabrication VI – MEMS and other processes		Lab 6: Anodic bonding
	12	Microfabrication VII – MEMS and other processes	Milestone 3 Outline & Refs due Milestone 4 Interview out Milestone 5 Draft out Milestone 6 Comments out	
7	13	Packaging of devices		Lab 7: Soft lithography part 1
	14	Integration of devices and systems	HW3 due HW4 out	
8	15	Microfluidics I - Concepts		Lab 8: Microfluidic phenomena
		FALL RECESS		

9	16	Microfluidics II - Components		Lab 9: Soft lithography part 2
	17	Microfluidics III - Systems	HW4 due HW5 out	
10	18	Lab on a Chip I – Introduction	Milestone 4 Interview due	Lab 10: Laminar flow and mixing in microchannels
	19	Lab on a Chip II – Applications		
11	20	Lab on a Chip III – Applications		Lab 11: Microfluidic control
	21	Draft review and comments	HW5 due Milestone 5 Draft due Milestone 6 Comments due HW6 out	
12	22	Microsensors		Lab 12: Microfluidic sensors
	23	Detection Schemes		
13	24	Microfabricated neural interfaces		Lab 13: Microelectrode neural interfaces
	25	Practice presentations (HW6)	HW6 due	
14	26	Drug delivery devices	Final Paper due	No Lab, Thanksgiving
	27	Thanksgiving – no class		
15	28	BioMEMS research at USC		No Lab, Final Projects due
	29	Final Project Presentations #1	Final Presentations due	
Finals		Final Project Presentations #2		

Assessment

Learners are assessed based on their grades from homework, laboratory exercises, and a course project as described below. Learners should expect 8 hours of work outside the class per week for this 4 unit course.

(1) Homework (40%)

Regular homework sets (~6) will be assigned and are due at the beginning of class on Thursdays. You will have 1-2 weeks to complete the assignments as indicated. Assignments test your understanding of material presented in class and your ability to apply that knowledge to engineering problems. From time to time, you may also be asked do your own research and discover new material as part of your homework assignment. Some homework problems will be completed in groups.

Please bring a physical copy to class (do not use the digital drop box). All derivations must be included with symbols before numbers are "plugged in." Units must accompany numerical results when applicable.

Collaboration is permitted on HW, however copying is not. You may not refer to materials from previous offerings of the class (homework, exams, notes, etc.) unless specifically allowed (i.e. final project papers). Collaboration is highly encouraged and includes discussions of concepts, exchange of information, and working together. Each student is responsible for individually preparing and fully understanding the work they submit. **Late homework is not accepted**. Legitimate medical excuses and emergency circumstances are the only exceptions.

(2) Laboratory Exercises (30%)

Laboratory exercises will take place each week. The laboratory sessions will be preceded by pre-lab activities (approximately 2 hours per week). These activities will take you through a range of activities from understanding the properties of materials, implications of scaling, application of concepts to achieving miniaturized device designs, and fabrication of biomedical microdevices. Many exercises will need to be completed individually; however, a subset of exercises will be completed in teams. Exercises will require that students prepare by reading the laboratory write-ups and following instruction of the teaching assistant who will guide and supervise the exercises. Grading will be based

on completion of the laboratory activities and laboratory write-up which will be handed in at the end of each lab. Attendance for the labs is mandatory. There will be no make-up laboratory sessions.

(3) Final Project (30%) = Milestones (10%) + Paper (10%) + Presentations (10%)

Students will work in teams of 2 or 3 (depending on class size) to research a special topic of their choice in bioMEMS. A list of possible topics will be provided. Groups may also choose a topic of their own with instructor approval.

Final project milestones will be assigned and be used in the calculation of your final project grade (each point earned typically equates to one percentage point of your overall grade; project milestones will account for 10% of the final grade).

A jointly written final paper reviewing the selected topic will account for 10% of the final grade. Final papers are due on **Nov xx** and will be checked using Turnitin. *There is a no-tolerance policy on plagiarism; any plagiarism will result in a "zero" grade for the final paper.*

The remaining 10% of the grade will be determined by the joint presentation prepared using Microsoft Powerpoint or similar software. Presentations will be given to the rest of the class on **Dec xx**. There will be a sign-up for presentation times.

There is no final exam for this class – instead we will use that time for the final presentations.

(4) How to get help:

The teaching assistant will hold office hours every week. The instructor will hold office hours by appointment. Also, the course uses the "Discussion Board" feature on Blackboard for posting questions on the course and homework. You are encouraged to use this tool as much as possible. Both the instructor and teaching assistant will regularly post responses that are available to the entire class. Students are also encouraged to post responses. Anonymous posting is enabled. Please plan ahead when posting questions related to homework; there is no guarantee that questions posted the night before the HW due date will be answered.

(5) Notes on Grading:

Final project grades will be determined by considering individual and team contributions. Final course grades are first computed as percentages and then curved.

(6) Notes on Cheating:

The policy is simple: Just don't do it! There is a no-tolerance policy on cheating. In this class, cheating is primarily copying HW from other students, current or past.

Other MEMS Classes

This introductory course will prepare students for advanced MEMS courses including BME-551, EE-607, and EE-608L. (AME-455, 537; BME-551; EE-438L, 480, 504L, 507, 508, 607, 608L; MASC-438L, 439, 512, 514L, 534 are also recommended for those interested in pursuing a MEMS career) There are new courses constantly being introduced and students are encouraged to look beyond this list.

Additional MEMS References

The following text may be useful for finding supplemental information. There are also many other texts not listed here but available in our USC libraries that may be useful for your projects and homework.

Nguyen N.T. & Wereley S. Fundamentals and Applications of Microfluidics, 2nd edition, Artech House, 2006.
Madou, M. Fundamentals of Microfabrication: the science of miniaturization, 2nd edition, CRC Press, 2002.
Saliterman, S. Fundamentals of BioMEMS and Medical Microdevices, Wiley/SPIE, 2006.
Kovacs, G.T.A. Micromachined Transducers Sourcebook, McGraw Hill, 1998.

Statement on Academic Conduct and Support Systems

Academic Conduct:

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, policy.usc.edu/scientific-misconduct.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
studenthealth.usc.edu/counseling

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call
suicidepreventionlifeline.org
Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention and Services (RSVP) - (213) 740-9355(WELL), press "0" after hours – 24/7 on call
studenthealth.usc.edu/sexual-assault
Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED)- (213) 740-5086 | Title IX – (213) 821-8298
equity.usc.edu, titleix.usc.edu
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
usc-advocate.symplicity.com/care_report
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office of Equity and Diversity |Title IX for appropriate investigation, supportive measures, and response.

The Office of Disability Services and Programs - (213) 740-0776
dsp.usc.edu
Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Campus Support and Intervention - (213) 821-4710
campussupport.usc.edu
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity at USC - (213) 740-2101
diversity.usc.edu
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
dps.usc.edu, emergency.usc.edu
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call
dps.usc.edu
Non-emergency assistance or information.

Office of the Ombuds - (213) 821-9556 (UPC) / (323-442-0382 (HSC)
ombuds.usc.edu
A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

Disclaimer
Taking this course **will not** guarantee or prepare you for a MEMS job in industry. MEMS is a tool and not a replacement for firm grounding in engineering fundamentals.

[1] BME Program Outcomes

Students who successfully complete the USC BME program should be able to:

a. an ability to apply knowledge of mathematics, sciences, and engineering
b. an ability to design and conduct experiments, as well as to analyze and interpret data
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
d. an ability to function on multidisciplinary teams
e. an ability to identify, formulate, and solve engineering problems
f. an understanding of professional and ethical responsibility
g. an ability to communicate effectively
h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i. a recognition of the need for, and ability to engage in life-long learning
j. a knowledge of contemporary issues
k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice