BME 444, Introduction to Biosensors and Diagnostics Devices

Units: 4

Term—Day—Time: Fall 2023, TBD, 110 minutes, two days a week

Location: TBD

Instructor: Maral Mousavi

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Teaching Assistant:

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Office Hours: TBD
Contact Info: TBD

Course Description

With the current COVID19 pandemic, importance of efficient and accessible testing biosensing platforms is well-recognized. Indeed, biosensors are an integral part of healthcare, precision medicine, and personal health monitoring. The purpose of the course is to provide a broad introduction to biosensor technology, and describe working principles and fundamentals of biosensors. The class will review: (i) Biosensors classification, (ii) Bio-recognition elements in biosensors, (iii) integration of engineering and biology for design of biosensors, (iv) design of point-of-care biosensors. This course has emphasis on practical and translational knowledge and will utilize demonstrations and discussions to provide hands-on skills and critical thinking skills as well as theoretical knowledge. This class has a lab component, and certain classes will be held in the BME instructions laboratory in Bigler Hall, as specified in the course schedule. Students will observe demonstrations and discuss experimental design, as well as perform simple measurements. Students should be prepared to read journal articles and engage in discussions in class.

Prerequisite(s): none
Co-Requisite(s): none
Concurrent Enrollment: none
Recommended Preparation: Basic knowledge of biology (BISC220L or equivalent courses), physics (PHYS 152L or equivalent courses), and chemistry (CHEM 105 A or equivalent courses) is recommended.

Learning Objectives

By the end of this course, students will be able to:

- Identify different classes of biosensors and describe their functioning principles
- Recognize limitations of biosensors in real-life applications
- Extend engineering principles to biosensor development
- Extend engineering principles to design point-of-care biosensors
- Apply the principles and concepts of transducers in biosensor design
- Demonstrate fundamentals of diagnostic devices and biomarker testing in biosensor design
- Analyze the technical and societal factors involved in point-of-care diagnostics and wearable sensors
- Develop communication and team-working skills to be able to work in interdisciplinary biomedical teams

Course Notes

This course is designed to introduce you to different aspects of biosensor design. Through homework assignments, exams, critical reading of primary literature, class presentations, and a collaborative project, students will learn design of biosensors. The timeline on which the material will be covered is provided below and is subject to change, at the instructor's discretion according to the class progress and needs.

Textbook: None, lecture notes and assigned reading.

Web page: A class website will be setup on Backboard containing information about the course: syllabus, reading handouts, homework assignments, grades, information about class activities, solutions to the homework sets, and an email directory of all students in the class. Use it as much as you find it useful. The web page can be accessed at: https://Blackboard.usc.edu.

Technological Proficiency and Hardware/Software Required

Access to the Microsoft Office Suite (or similar software for writing/editing reports, and plotting data) is required to complete the postlab assignments and homework questions. A personal computer will be needed for completing assignments and accessing class content. Class will be recorded, and live Zoom will be held to accommodate remote attendance that might be necessary due to medical issues.

USC Computing Center Laptop Loaner Program: Information Technology Services provides loaner laptops at the general-use computing center in the Ahmanson Information Commons at Leavey Library. Learn more: https://itservices.usc.edu/spaces/laptoploaner/

Zoom Meeting: Zoom provides a high-quality, mobile-optimized, video and audio conferencing service for free to all USC students. Learn more: https://keepteaching.usc.edu/students/student-toolkit/classroom/zoom/

Blackboard Help for Students: Access instructions on how to utilize the Blackboard platform. https://keepteaching.usc.edu/students/student-toolkit/classroom/blackboard/

Software Available to USC Campus: All software needed for this class are available through USC. Learn more at: https://software.usc.edu/

Required Readings and Supplementary Materials

No material needs to be purchased for this course. Assigned reading will be posted to Blackboard; these readings are current journal publications that are available to USC students.

Optional Readings and Supplementary Materials

Articles will be introduced during class and will be uploaded on Blackboard.

Description and Assessment of Assignments

Grading rubric for final project is at the end the syllabus. For homework, exams, and postlab assignments, answer keys will be posted the day after each assignment is due and grading will be completed based on the answer key.

The final grade will be based on the following:

(1) Quizzes
Two quizzes will be posted to the Blackboard. Quiz 1 will be completed day 1 of the class, and quiz 2 will be completed in the last week of class. The purpose of this quiz is to gauge the class familiarity with class topics and adjust the class content appropriately. By completing this quiz, students will receive the full credit (regardless of the selected answers).

(2) Journal Presentations
Each student will be asked to present a journal article relevant to class topics throughout the semester. There will be a 5-minute presentation, followed by 5 minutes of discussions in class. Articles will be posted to Blackboard and will be announced in class. Students will be offered opportunities to volunteer to present articles.

(3) Homework
Two homework assignment will be posted during the semester (each worth 100 points, 10 questions). The purpose of these homework assignments is to prepare the students for the upcoming exams.

(4) Postlabs
Lab sessions are held in BHE B8 as stated in the Syllabus, and class schedule. Students should review the prelab before coming to the lab classes. All students should complete online chemical safety training, and come with closed toe shoes and wear long pants when present in the lab. Lab coats and safety glasses are available at BHE B8. After each lab session, the collected data will be shared with the students along with a short postlab question list. Students will process the data and answer questions to ensure gaining of practical knowledge.

(5) Final Exam, Final Exam (cumulative)

(6) Exam I, TBD (25%)

(7) Class participation (5%)
See the participation Section for more details.

(8) Final project
a. The goal of this final project is to cultivate team-working skills of the students, and provide an opportunity to exercise the theoretical knowledge gained in the classroom towards real-life medical problems. The project entails identifying an unmet medical need and designing a biosensor to address this need (using the knowledge gained in the classroom). Examples of such projects include: (i) Biosensor for monitoring liver injury at the point-of-care, (ii) Smart-phone compatible biosensor for management of food intake in patient's suffering from chronic kidney disease
b. Students will be asked to work in teams of 2-4 to complete the final project.
c. The team should submit a written document (template will be provided, 10% of grade) with appropriate citations, motivation of the work, proposed design, control experiments, and discussion about regulatory process for testing of the device. Each team will present the work in the classroom (10-15 minutes duration of presentation, no limitation on number of slides, 8% of grade). One grade will be assigned to all the team members for their written report and oral presentation. All students are expected to contribute equally towards the final project. A one-page document stating individual contributions from each team-member should be submitted after the in-class presentations. A rubric for grading of final written report and oral presentation is provided (please see the Addendum).

Participation

Class participation includes attendance in lecture sessions and engagement in discussions class and answering of questions. Participation in lab classes are required, and absence in lab sessions should be coordinated with the instructor. During classes, students are expected to participate in the in-class design exercises and take part in presenting their findings to class. Students are expected to provide feedback to their peers during their final project presentation, and submit evaluation forms on other projects. Class participation constitutes 5% of the final grade.

Grading Breakdown

Grades will be based on the individual homework assignments and exams. The weighting scheme for the final grade is below:

Exam I	**25%**
Final Exam	**25%**
Quizzes	**2%**
Class Participation	**5%**
Homework Assignments	**11%**
Final Project	**18**
Oral (8%)	
Written (10%)	
Post Labs	**8%**
Journal Presentation	**6%**
Total	**100**

Assignment Submission Policy

All assignments should be submitted electronically via the Blackboard platform. Class has no late policy. Late submissions (even if it is by a minute) is not accepted under any circumstances (unless there is a medical emergency with a valid note), and will result in zero points received for that assignment. Students are responsible to allow sufficient time for uploading the files and submission. We recommend starting early and not leaving submission to the last minute. All cutoff time for submissions on 11:59 pm of the announced day (usually Sundays).

Course Specific Policies

Late Policy: Class has no late policy. Late submissions (even if it is by a minute) is not accepted under any circumstances (unless there is a medical emergency with a valid note), and will result in zero points received for that assignment. Students are responsible to allow sufficient time for uploading the files and submission. We recommend starting early and not leaving submission to the last minute. All cutoff time for submissions on 11:59 pm of the announced day (usually Sundays).

Attendance

Attendance is not graded, but class participation is. Please see the Participation section for more details.

Classroom norms

[Classroom norms describe the behaviors that are encouraged and discouraged during class. They can be a powerful tool for establishing a supportive learning environment. Refer to the CET resource, A menu of discussion norms.]

Zoom etiquette

Students are required to follow the internet etiquette during Zoom participation, as specified by USC: https://cet.usc.edu/teaching-resources/netiquette-considerations/ Students are encouraged to contact the instructor if there are any concerns related to complying with this policy.
Class participation is required even during Zoom attendance. Students are required to keep their videos on and participate in in-class activities.

Course Content Distribution and Synchronous Session Recordings Policies

USC has policies that prohibit recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Recording a university class without the express permission of the instructor and announcement to the class, or unless conducted pursuant to an Office of Student Accessibility Services (OSAS) accommodation. Recording can inhibit free discussion in the future, and thus infringe on the academic freedom of other students as well as the instructor. (Living our Unifying Values: The USC Student Handbook, page 13).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which had been distributed to students or in any way had been displayed for use in relationship to the class, whether obtained in class, via email, on the internet, or via any other media. (Living our Unifying Values: The USC Student Handbook, page 13).

Course Evaluations

Course evaluation occurs at the end of the semester university-wide. It is an important review of students' experience in the class. Student feedback is used to improve the class content for next offerings. Learning Experience Evaluations are your opportunity to provide feedback to your instructor. USC and its faculty take these evaluations very seriously, as they provide valuable information that faculty and schools can use to improve teaching. It is important to remember that the learning process is collaborative and requires significant effort from the instructor, individual students, and the class as a whole. Please provide a thoughtful assessment of their experience, as well as of their own effort, with comments focused on specific aspects of instruction or the course. Comments on personal characteristics of the instructor are not appropriate and will not be considered. Evaluations should be completed individually with no undue influence by either a student or instructor. Should any inappropriate behavior occur, it will be reported to the Office of Institutional Research.

Course Schedule

The class progress will follow according to Table 3. Please note that small changes to this schedule might be made to accommodate the class needs each year.

Table 1: Course Schedule.			
	Topics/Daily Activities	**Readings/Preparation**	**Deliverables**
Week 1	• Discussions on class structure, grading, exams, final project Introduction to biosensors, Biosensor classification, Main elements in biosensors, Characteristics of signals, Overview on basics of detection methods, discussions on biofluids and systems, types of analytes detected, overview of glucometers, • History of electrochemistry, and types of cells, conductivity in solutions, review on chemical structure of metals and ionic compounds	Watch the documentary on Theranos. Recommended Reading: Bad Blood: Secrets and Lies in a Silicon Valley, by John Carreyrou	Quiz 1 (non-graded topic familiarity)
Week 2	• Introduction to electrochemical detection methods, redox processes, and electron transfer, electron transfer from the perspective of molecular orbitals, salt bridge and batteries, standard reduction potentials • Electrochemical cells for measurements, processes at electrode surface, and mass transport of material to the electrode surface, 2 vs. 3 electrode setup for measurements		
Week 3	• Active DC electrochemical techniques: voltammetry and amperometry, Electrochemical cells for measurements, processes at electrode surface, and mass transport of material to the electrode surface, Active vs. passive techniques, • No class, labor day.	Homework 1 posted. First assigned reading journal article posted.	
Week 4	• Lab day (class meets in BHE for the first lab) Demonstration of electrochemical voltametric techniques • Active DC electrochemical techniques: voltammetry and amperometry, Details of voltage pulses in cyclic voltammetry, charging current, electrode surface area, electrode polishing, establishing current and concentration correlation.	Prelab 1 should be reviewed before the lab class. Postlab 1 assignment will be posted. Assigned journal reading posted.	In class journal presentation
Week 5	• Quantifying diffusion, planar vs. radial diffusion, Pulsed Electrochemical Techniques, Overpotential • Active DC electrochemical techniques, Self-assembled monolayers, effect of scan rate, immobilized enzyme-electrodes, Review on Enzyme Kinetics and Protein Structure, Journal Club Presentation	Assigned journal reading posted.	Postlab 1 due In class journal presentation
Week 6	• Immobilized enzyme-electrodes continued, immobilization methods on electrode surfaces mediators, journal presentation by students, Polarizable electrodes • Gibbs free energy, Review on Equilibrium, Redox Couples and Reference Electrodes, Liquid Junction Potential, Clark Electrode, Glucometers,	Assigned journal reading posted. Answer key for postlab 1	In class journal presentation Team selection for final project Homework 1 due

	Introduction to Potentiometry for small molecule and ion detection		
Week 7	• Aptamer-based detection, Potentiometry continued, Activity vs. concentration, Materials and types of carbon, Integrated sensors • Lab. 2, enzymatic biosensors	Prelab 2 should be reviewed before the lab class. Postlab 2 assignment will be posted. Assigned journal reading posted.	In class journal presentation
Week 8	• Potentiometry continued, Paper-based microfluidics • PDMS and lithography, Journal presentation, electrochemical immunosensors	Assigned journal reading posted.	Postlab 2 due EXAM 1 In class journal presentation
Week 9	• Lab 3 (potentiometric sensing) • Examples of electrochemical sensors for detection of different molecules, Impedimetric detection, journal presentation	Assigned journal reading posted. Prelab 3 should be reviewed before the lab class. Postlab 3 assignment will be posted. Answer key for exam 1 Answer Key for postlab 2	Meet with instructor to discuss final project idea In class journal presentation
Week 10	• Electrochemical detection continued, field-effect sensors, journal presentations • Optical Detection Methods, UV-Vis Spectroscopy	Assigned journal reading posted. Homework 2 posted.	Postlab 3 due In class journal presentation
Week 11	• Fluorescence Spectroscopy, Colorimetric biosensors, Journal Presentations • Lasers, FRET Sensors	Answer Key for postlab 3	Meet with instructor again to discuss final project design
Week 12	• ELISA Assay, Lateral Flow Assays, journal presentations • Lab 4: screen-printing, paper-based microfluidics, electrodeposition	Assigned journal reading posted. Prelab 4 should be reviewed before the lab class. Postlab 4 assignment will be posted.	In class journal presentation
Week 13	• Amplification Techniques (PCR, LAMP), journal presentations • Surface Plasmon Resonance, Magnetic labeling	Assigned journal reading posted.	Postlab 4 due Homework 2 due

			In class journal presentation
Week 14	• Lab. 5: running competitive ELISA assay, and confirmation of Beer-Lambert law using food dye solutions, PDMS microfluidics	Answer key to homework 2 Answer key to postlab 4 Prelab 5 should be reviewed before the lab class. Postlab 5 assignment will be posted.	Optional: Meet with instructor again to discuss final project design In class journal presentation
Week 15	• Integrated sensors, special topics and device reviews (based on available time) • Presentations of Final Project by students and in class discussion Class Evaluation	Optional journal reading posted.	Postlab 5 due Final project presentation due Quiz 2 (non-graded topic familiarity)
FINAL	Final Exam (Cumulative) Written report due	According to the final exam schedule in the USC *Schedule of Classes* at classes.usc.edu.	

Statement on Academic Conduct and Support Systems

Academic Integrity

This course will follow the expectations for academic integrity as stated in the USC Student Handbook, as detailed here and in the subsequent "Statement on Academic Conduct and Support Systems" section.

The University of Southern California is a learning community committed to developing successful scholars and researchers dedicated to the pursuit of knowledge and the dissemination of ideas. Academic misconduct, which includes any act of dishonesty in the production or submission of academic work, comprises the integrity of the person who commits the act and can impugn the perceived integrity of the entire university community. It stands in opposition to the university's mission to research, educate, and contribute productively to our community and the world.

All students are expected to submit assignments that are original work and prepared specifically for the course/section in this academic term. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s). You may not record nor distribution any synchronous and asynchronous course content outside of the learning environment. Students suspected of engaging in academic misconduct will be reported to the Office of Academic Integrity, and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

Students are expected to spend approximately eight hours per week on readings and assignments. Students are expected to do their own homework assignments and should completely understand everything that they submit as their own. It is anticipated and expected that students consult one another for clarification of concepts, advice, to compare the final numerical homework solution, etc. It is not acceptable to show someone else your written homework, even if it is easier than explaining a concept verbally. You may also use whatever materials you find on the web, in other texts, or other sources to assist in preparing your

homework. Also, copying homework prepared by another student and plagiarizing are strictly prohibited. Violations of this policy will result in an **automatic F** in the class and filing of an academic misconduct report to the Office of Student Conduct. All students are expected to adhere to the USC standards of Academic Integrity (http://www.usc.edu/student-affairs/SJACS/docs/AcademicIntegrityOverview.pdf and http://www.usc.edu/student-affairs/SJACS/docs/GradIntegrity.pdf).

Collaboration. In this class, you are expected to submit work that demonstrates your individual mastery of the course concepts.
Group work. Unless specifically designated as a 'group project,' all assignments are expected to be completed individually.

Other violations of academic integrity include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), collusion, knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university. All incidences of academic misconduct will be reported to the Office of Academic Integrity and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see the student handbook or the Office of Academic Integrity's website, and university policies on Research and Scholarship Misconduct.

Please ask your instructor if you are unsure what constitutes unauthorized assistance on an exam or assignment, or what information requires citation and/or attribution.

Students and Disability Accommodations:

USC welcomes students with disabilities into all of the University's educational programs. The Office of Student Accessibility Services (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at osas.usc.edu. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

988 Suicide and Crisis Lifeline - 988 for both calls and text messages – 24/7 on call
The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline is comprised of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL) – 24/7 on call

Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

Office for Equity, Equal Opportunity, and Title IX (EEO-TIX) - (213) 740-5086
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
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

The Office of Student Accessibility Services (OSAS) - (213) 740-0776
OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

USC Campus Support and Intervention - (213) 740-0411
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity, Equity and Inclusion - (213) 740-2101
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
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) 442-1200 – 24/7 on call
Non-emergency assistance or information.

Office of the Ombuds - (213) 821-9556 (UPC) / (323-442-0382 (HSC)
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.

Occupational Therapy Faculty Practice - (323) 442-2850 or otfp@med.usc.edu
Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.

Grading Rubric for Oral Presentations

Category	Scoring Criteria	Total Points	Score
Organization (15 points)	Information is presented in a logical sequence.	10	
	Presentation appropriately cites requisite number of references.	5	
Content (65 points)	The motivation of the work and prior art is clearly explained.	15	
	Technical terms are well-defined.	5	
	Presentation contains accurate information.	10	
	Material included is relevant to the overall goal of the project.	5	
	Methodology is clearly explained.	15	
	Conclusion summarizes the key point of the work.	5	
	Length of presentation is within the assigned time limits.	10	
Presentation (20 points)	Speaker maintains good eye contact with the audience and is appropriately animated (e.g., gestures, moving around, etc.).	5	
	Speaker uses a clear, audible voice.	5	
	Visual aids are well prepared, informative, effective, and not distracting.	10	
Score	**Total Points**	**100**	

Grading Rubric for Written Report

Category	Scoring Criteria	Total Points	Score
Introduction (45 points)	Motivation of the work is presented clearly.	10	
	Prior work is clearly explained and cited.	15	
	Gaps in the literature are explained.	10	
	Proposed method and element of novelty is explained clearly.	10	
Discussions (30 points)	Details of proposed method is explained.	10	
	Control experiments are discussed.	5	
	Design and fabrication are depicted using illustrations and figures.	10	
	Appropriateness of the proposed approach and to the medical need is discussed.	5	
Conclusion (10 points)	The key findings in the proposed approach are summarized.	5	
	Advantages and disadvantages of the proposed approach are discussed.	5	
Grammar and Writing (15 points)	Writing is grammatically correct.	5	
	Words have correct spelling.	5	
	Writing is simple and understandable and avoids use of unnecessary jargon and complicated wording.	5	
Score	**Total Points**	**100**	