



BME 599: Biosensors and Diagnostic Devices for Healthcare Applications

Units: 4

Fall 2020— Tuesdays and Thursdays, 9:30—10:50 am

Location: To be determined

Instructor: Maral Mousavi

Office: DRB 170

Office Hours: To be determined

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Catalogue 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. The class will dive deeper into electrochemical biosensors, and cover (i) electrochemical enzyme sensors (i.e., glucose sensing), (ii) potentiometric sensors, (iii) voltammetric and amperometric sensors, and (iv) impedance-based sensors. This course has emphasis on practical and translational knowledge and will utilize discussions to provide critical thinking skills and design skills as well as theoretical knowledge (this is not a lab class).

Learning Objectives, Specific Outcomes of Instruction, and Relationship to Program Outcomes

1. Learning objectives

- Be able to identify different classes of biosensors and describe their functioning principles
- Be able to recognize limitations of biosensors in real-life applications
- Be able to extend engineering principles to biosensor development
- Be able to extend engineering principles to design point-of-care biosensors
- Understand the principles and concepts of transducers and their application in biosensor design
- Understand fundamentals of diagnostic devices and biomarker testing in biological fluids
- Understanding 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

2. Course outcomes

- Outcome 1: Apply principles and concepts of biology and engineering to design biosensors
- Outcome 2: Apply principles and concepts of electronics and electrochemistry to design electrochemical biosensors
- Outcome 3: Recognize different types of transducers, and their application in biosensor design
- Outcome 4: Apply principles and concepts of sensing and engineering to (i) design biosensors for detection of markers in biofluids, and (ii) be able to evaluate quality of biosensors

- Outcome 5: Apply engineering tools to evaluate parameters needed for point-of-care health screening and mobile-health, and design of appropriate point-of-care diagnostic devices
- Outcome 6: Work in a team to design biosensors and identify applications

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) required.

Textbook: None, lecture notes only.

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 and the class progress.

Web page: A class website will be setup on Blackboard 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>.

Office Hours: Time and location for office hours will be identified at the beginning of first session of the class. Students are encouraged to take advantage of office hours

Class Format and Grading Policy:

The final grade will be based on the following:

- (1) Homework (35%)
 - a. Homework assignments each containing 3-10 questions will be distributed through the semester. Homework assignments are designed to 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. Appropriate reading (journal articles, reports, etc.) will be assigned to assist in homework and learning of the class content.
 - b. All questions on homework should be posted to the appropriate discussion board on Blackboard.
 - c. All homework assignments are due by 11:59 pm on the date indicated.
 - d. Homework assignments must be submitted via Blackboard. Only one pdf file should be submitted for each homework assignment. You can submit latex pdf files, word converted pdfs, or scanned images which are converted to pdf format.
 - e. Late homework submissions are not accepted under any circumstances. Start your homework assignments early. Each student gets a one-time 48-hour late submission pass to be used in case of emergencies.
 - f. There will be 4-8 homework assignments.
 - g. Show all work. All derivations must be included with symbols before numbers are "plugged in." Units must accompany numerical results when applicable.
 - h. Collaboration is permitted on HW, however copying is not. 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. Review the university and course Integrity Policies (links below).

They will be strictly enforced. This class has a **no-tolerance** policy on academic integrity violations – copying is a form of cheating.

(2) Exam 1 (25%)

(3) Exam 2 (25%)

(4) Journal Club Summaries and Presentations (5%)

Journal articles (10-15) relevant to the course materials will be assigned to the class. Students will be asked to submit five brief summaries of the articles during the semester. During the semester, each student will present (10-15 min. duration of the presentation) one journal article to the classroom, and analyze the approach and results with a critical view.

(5) Final project (10%)

- 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 new 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 (less than 5 pages excluding references, single space, font size between 10-12 Times New Roman or Calibri) 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). 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).

Grading Breakdown

Grades will be based on the individual homework assignments and exams.

The weighting scheme for the final grade is below:

Exam 1	25%
Exam 2	25%
Homework Assignments	35%
Journal Club	5%
Final Project	10%

Total: 100%

Homework/Academic Integrity Policy

Students are expected to spend approximately six 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>).

Course Schedule: A Weekly Breakdown (this schedule is tentative and subject to change)

	Topics Covered
Week 1 08/24–08/28	Introduction to biosensors Biosensor classification Main elements in biosensors
Week 2 08/31–09/04	Biomolecules in biosensors: DNA, enzyme, antibody, antigen, protein, peptide, aptamer
Week 3 09/07–09/11	Biomolecules in biosensors continued, Amplification Techniques (PCR), ELISA (enzyme-linked immunosorbent assay)
Week 4 09/14–09/18	Basics of detection methods: Fluorescence Spectroscopy, UV-Vis Absorption and Emission, Surface Plasmon Resonance, Magnetic labeling, Electrochemical Detection
Week 5 09/21–09/25	Introduction to electrochemical detection methods, redox processes, and electron transfer
Week 6 09/28–10/02	Electrochemical cells for measurements, processes at electrode surface, and mass transport of material to the electrode surface Exam 1
Week 7 10/05–10/09	Active DC electrochemical techniques: voltammetry and amperometry, immobilized enzyme-electrodes
Week 8 10/12–10/16	Active DC electrochemical techniques: Impedance Spectroscopy
Week 9 10/19–10/23	Potentiometry for small molecule and ion detection
Week 10 10/26–10/30	Fluorescence and colorimetric biosensors
Week 11 11/02–11/06	Detection of viruses and bacteria
Week 12 11/09–11/13	Point-of-care sensing: microfluidics and paper-based diagnostics Class Evaluation Exam 2
Week 13 11/16–11/20	Point-of-care sensing: yarn and textile-based sensing Presentations of Final Project by Students
Week 14 11/23–11/24	Homework Review Presentations Continued
Final Week 12/02–12/09	Final Project, Written Report Due

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”. 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. The university prohibits discrimination or harassment based on the following *protected characteristics*: race, color, national origin, ancestry, religion, sex, gender, gender identity, gender expression, sexual orientation, age, physical disability, medical condition, mental disability, marital status, pregnancy, veteran status, genetic information, and any other characteristic which may be specified in applicable laws and governmental regulations. The university also prohibits sexual assault, non-consensual sexual contact, sexual misconduct, intimate partner violence, stalking, malicious dissuasion, retaliation, and violation of interim measures.

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 Support and Advocacy - (213) 821-4710

ucsa.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.

Addendum

Scoring 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 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	

Scoring 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	