Engineering Faculty Document No. 15-22
December 1, 2021

TO: The Faculty of the College of Engineering
FROM: The Faculty of the Weldon School of Biomedical Engineering
RE: Changes to BME 58100/ECE 52600/ME 59700 Fundamentals Of MEMS And Micro-Integrated Systems

The Faculty of the Weldon School of Biomedical Engineering, the School of Electrical and Computer Engineering, and the School of Mechanical Engineering have approved the following change in title and description of the course listed below. This action is now submitted to the Engineering Faculty with a recommendation for approval. Curriculog link: BME - 58100 - Bio-Micro-Electro-Mechanical Systems (BioMEMS) & Biomedical Microsystems | Curriculog

FROM: **BME 58100 Fundamentals Of MEMS And Micro-Integrated Systems**
Term Offered: Spring, Lecture 3, Cr. 3
Prerequisite: Sr. or Graduate standing

Description: Key topics in micro-electro-mechanical systems (MEMS) and biological micro-integrated systems; properties of materials for MEMS; microelectronic process modules for design and fabrication. Students will prepare a project report on the design of a biomedical MEMS-based micro-integrated system.

TO: **BME 58100 Bio-Micro-Electro-Mechanical Systems (BioMEMS) & Biomedical Microsystems**
Term Offered: Spring, Lecture 3, Cr. 3
Prerequisite: Sr. or Graduate standing

Description: This course covers key topics in bio-micro-electro-mechanical systems (BioMEMS) and micro-integrated systems. Properties of useful materials will be discussed in context to BioMEMS. Micro-electronics process modules used in the design and fabrication of BioMEMS and micro-integrated systems will be presented. Applications of these systems in a variety of medical practices will be discussed in detail.

REASON: This course provides a thorough study of bio-micro-electro-mechanical systems (BioMEMS) and micro-integrated system with a solid foundation for graduate students to utilize the biomedical designs to their fullest potential. This course is clearly differentiated from traditional MEMS courses because its focus is within the context of biocompatible materials and devices for their uses in many wearable and implantable healthcare applications of growing importance at Purdue. It was developed by Professor Babak Ziaie and offered annually in ECE (52600), and then modified since 2018 by Professor Chi Hwan Lee and cross-listed as BME 58100/ME 52600/ECE 52600.

David M. Umulis
Dane A. Miller Head and Professor
Weldon School of Biomedical Engineering

Bio-Micro-Electro-Mechanical Systems (BioMEMS) & Biomedical Microsystems

Spring 2022

Instructor: Professor Chi Hwan Lee
Contact Info: MJIS 2086, lee2270@purdue.edu
Lecture Info: TBD
Office Hours: TBD

Prerequisite:
Sr. or Graduate standing

Course Descriptions:
Key topics in bio-micro-electro-mechanical systems (BioMEMS) and micro-integrated systems will be presented. Properties of useful materials will be discussed in context to BioMEMS. Micro-electronics process modules used in the design and fabrication of BioMEMS and micro-integrated systems will be presented. Applications of these systems in a variety of medical practices will be discussed in detail.

Learning Outcomes:
Upon completion of the course each student will be able to
1) Apply advanced engineering principles to model, solve, or analyze biomedical engineering problems.
2) Formulate appropriate and quantitative design specifications and evaluate potential design solutions in terms of realistic constraints.
3) Describe the challenges associated with interactions between bio-MEMS devices/strategies and living biology to address current unmet clinical needs.

Brief Course Outline:

1) Introduction to BioMEMS: Brief outline of BioMEMS, its historical roots, and most recent developments in the area.

2) Scaling: How different forces scale to the micro and nano-levels, which are scaled better than others?

3) Fabrication Processes: A quick review of some basic steps used in the fabrication of integrated circuits (diffusion, oxidation, thin film deposition etc.) followed by BioMEMS-specific fabrication methods covering bulk and surface micromachining, soft lithography, and polymer/soft micromachining.

4) Properties of Materials/Biomaterials: Introduction to electrical, mechanical, and thermal properties of matter commonly used in the design of BioMEMS sensors and actuators.

5) Structural Elements: Introduction to simple mechanical elements and structures such as cantilever beams and plates/membranes used in many BioMEMS sensors and actuators covering the deflection/load relationships and locations of maximum stress.

6) Lumped Element Models: Discussing various lumped-elements (R, L, C, and energy sources) used to model mechanical and other systems with electrical elements.

7) Transduction Mechanisms: Discussing major sensor and actuator transduction mechanisms such as capacitive/electrostatic, piezoresistive, piezoelectric, thermal, and magnetic.

8) Interface Electronics: Brief overview of some of the more important interface circuits (e.g., Wheatstone bridge) used to connect sensors to the electronics.

9) Soft BioMEMS and robotics: Polymeric and stretchable sensors and actuators used in wearable and soft robotics. Fabrication, actuation, and applications.

10) Basic Biology for BioMEMS: A 101 level review of important biological concepts used in biosensor and BioMEMS design, such as bio-macromolecules (DNA and protein), antibodies/enzymes for analyte capture, DNA technology (recombinant DNA, sequencing), and cellular components.

11) Biosensors and BioMEMS; Examples of most recent technologies in bio-sensing, bio-printing, and BioMEMS.

12) Micro-fluidics and Lab-on-a-chip Devices; Physics of flow at microscale, microfluidic components (channels, valves, pumps, mixers), selected examples of lab-on-a-chip devices such as point-on-care diagnostics and organ-on-a-chip.

Textbooks (Optional):

- Chang Liu, *Foundations of MEMS*, 2nd Edition, Pearson/Prentice Hall, 2011. (Introductory-Intermediate)
- Stretchable Electronics, Takao Someya, WILEY-VCH. ISBN: 978-3-527-32978-6 (2013). (This book is available to download free in Purdue library. Handouts will be distributed when lecture topics are not included in the book.)
- Gregory T.A. Kovacs, *Micromachined Transducers Sourcebook*, McGraw Hill, 1998. (Introductory)
- Albert Foch, *Introduction to BioMEMS*, CRC Press, 2013. (Introductory-Intermediate)
- Ellis Meng, *Biomedical Microsystems*, CRC Press, 2011. (Introductory)
- S. S. Saliterman, *Fundamentals of BioMEMS and Medical Microdevices*, SPIE, 2006. (Introductory)
- G. Urban, *BioMEMS*, Springer, 2006. (Introductory)
- Ville Kaajakari, *Practical MEMS*, Small Gear Publishing, 2009. (Intermediate-Advanced)

- Stephen Senturia, *Microsystem Design*, Springer, 2000. (Intermediate-Advanced)

Handbooks (Optional):

- Marc Madou, *Fundamentals of Microfabrication and Nanotechnology*, CRC Press, 2011.
- M. Gad-el-Hak, *The MEMS Handbook*, CRC Press, 2005.

Supplemental books (Optional): These are some classic books written for general/lay readers. The first two discuss mechanical properties of materials and structures and the last one is a good introduction to molecular biology

- *The New Science of Strong Materials or Why You Don't Fall through the Floor* (Princeton Science Library) – by J. E. Gordon.
- *Structures: Or Why Things Don't Fall Down* – by J. E. Gordon
- *DNA: A Graphic Guide to the Molecule that Shook the World* by Israel Rosenfield, Edward Ziff, and Borin Van Loon.

On Line Resources: Brightspace will be used to communicate, track grades, post lectures (when available), document assignments, and updates to readings. Please check Brightspace often.

Grading:

Homework Assignments:	20%
Quiz 1:	10%
Quiz 2:	10%
Midterm Exam:	25%
Final Exam:	35%
Total	**100%**

Grade Scale: The following grading scale is just for your reference. Based upon ensemble class performance, final grades will be curved up by the instructor if appropriate. The instructor will update on how to curve up the grades after each exam. Students are welcome to discuss his/her progress with the instructor throughout the semester.

>95%	A+
90-95%	A
87-90%	A-
85-87%	B+
80-85%	B
78-80%	B-
75-78%	C+
70-75%	C
65-70%	C-
60-65%	D
<60	F

Final project (currently limited during the COVID-19 pandemic): A final project will be included as soon as the COVID-19 virus runs its course. This will require you to integrate and apply knowledge and skills obtained throughout the course to investigate an area of soft bioelectronics and their applications in biomedical devices. These projects will be completed in self-selected teams of 2 to 3 students over the last month of the course. A formal presentation of the findings will be presented to the class during the final week(s) of lectures. The final project reports and presentations will be evaluated by your peers, the instructor, and the TA for clarity, logical progression, in-depth understanding, correctness and significance of findings, in such order.

COURSE POLICIES:

- **Come to class on time.**
- **No devices** (e.g. cell phones, laptops) in lecture. Come to focus on this course.
- **Absence for medical issue, family emergency or extracurricular activity:** In the event that you need to be absent from class due to a medical issue, family emergency or extracurricular activity, please communicate with the instructor as far in advance as possible. This will allow a discussion regarding the nature/duration of the absence and how the learning outcomes associated with any missed class activities may be addressed. As per university policy: "ultimately students are responsible for all required coursework and bear full responsibility for any academic consequences that may result due to absence."
- **Only in well-documented emergency situations** will students be allowed to take submit assignments or make presentations at time other than the officially announced date; no other excuses are accepted.
- You cannot do extra work after the semester is over to change your grade. **All grades are FINAL once submitted.**
- An **incomplete grade** is only for students who do most of the required work (at least 75%) and at the end of the semester cannot finish the course due to a **well-documented emergency**.
- If you have any issue or difficulty with the course you need to **contact the instructor during the semester and seek help in advance.**
- In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Here are ways to get information about changes in this course.
  - Course webpage on Purdue Brightspace
  - Instructor's email
  - Instructor's phone

CODE OF CONDUCT:

In addition to issues covered under Purdue's academic integrity statement, students and staff affiliated with this course are expected to adhere to the following Code of Conduct:

As a student or staff member affiliated with the course, I will support an environment of mutual respect, fairness, accountability, collaboration, partnership, honesty and integrity.

- I will be honest, fair, respectful and courteous in my dealings with students, staff members and other individuals whom I encounter in the activities of the course. This applies both in formal activities such as lecture and informal activities such as team meetings and collaboration sessions.
- I will work within a team to achieve a successful project outcome as well as to advance the professional skills of all members of the team. I understand that members of my team will bring a diverse set of ideas, technical skills and academic/professional experience.
- In peer-review exercises and staff-reviewed assignments, I will provide and/or receive constructive criticism in a respectful manner.

PURDUE UNIVERSITY ACADEMIC INTEGRITY STATEMENT:

Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing integrity@purdue.edu or by calling 765-494-8778. While information may be submitted anonymously, the more information that is submitted provides the greatest opportunity for the university to investigate the concern.

PURDUE HONORS PLEDGE:

As a boilermaker pursuing academic excellence, I pledge to be honest and true in all that I do. Accountable together - we are Purdue. (composed by students)

ACADEMIC DISHONESTY POLICIES:

Every member of the Purdue community is expected to practice honorable and ethical behavior both inside and outside the classroom. Any actions that might unfairly improve a student's score on homework, quizzes, or examinations will be considered cheating and will not be tolerated.

Examples of cheating include (but are not limited to):

- Sharing results or other information during an examination.
- Bringing forbidden material or devices to an examination.
- Working on an exam before or after the official time allowed.
- Requesting a re-grade of answers or work that has been altered.
- Submitting homework that is not your own work or engaging in forbidden homework collaborations.
- Let others use your clicker and pretend to be you in class

At the instructor's discretion, cheating on an assignment or examination will result in a reduced score, a zero score, or a failing grade for the course. All occurrences of academic dishonesty will be reported to the Assistant Dean of Students and copied to the ECE Associate Head of Education. If there is any question as to whether a given action might be considered as cheating, please see the instructor or the teaching assistant before you engage in any such action.

MENTAL HEALTH RESOURCES:

- **If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try WellTrack, https://purdue.welltrack.com/.** Sign in and find information and tools at your fingertips, available to you at any time.
- **If you need support and information about options and resources**, please see the Office of the Dean of Students, http://www.purdue.edu/odos, for drop-in hours (M-F, 8 am- 5 pm).
- **If you're struggling and need mental health services**: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at (765)494-6995 and http://www.purdue.edu/caps/ during and after hours, on weekends and holidays, or by going to the CAPS office of the second floor of PUSH during business hours.

EMERGENCY PREPAREDNESS

Purdue University is actively preparing for natural disasters or human-caused incidents with the ultimate goal of maintaining a safe and secure campus. Please review information (and sign up for emergency alerts) at: https://www.purdue.edu/ehps/emergency_preparedness/ .

General procedures:

- For any emergency call 911 (from a Purdue "land line", 911 operator will know the phone's location; from a cell phone, you will need to tell the operator your location)
- There are nearly 300 Emergency Telephone Systems throughout campus that connect directly to the Purdue Police Department (PUPD). If you feel threatened or need help, push the button and you will be connected to the PUPD.
- **Fire alarm:** In the event of a fire alarm, we will immediately stop lecture, evacuate the building and proceed to one of the locations indicated in red in the figure below.
    - Do not use the elevator.
    - Notify others on your way out
    - If possible, help those needing assistance

- The chart below indicates the recommended options/considerations for various types of **Shelter in Place** requirements. If we are notified of a **Shelter in Place** requirement, we will immediately stop lecture and move to the recommended location.

Emergency	Shelter in Place Options/Considerations
Weather-Related - Tornado Warning	Basement corridors, basement offices, basement restrooms Or the lowest level of the building (stay away from windows and doors)
Hazardous Materials (HAZMAT) Release	Remain or find an unaffected office or work area and close windows and doors.
Active threat, such as a shooting	Seek a safe location, preferable a room without windows that can be locked or secured by barriers.