Introduction

This course presents an overview of various thin film and thick film processing, microfabrication and micromachining techniques utilized for producing microsensors, microelectromechanical systems (MEMS) and microactuators. Device design for electrostatic, piezoresistive, piezoelectric, electromagnetic, thermal, optical, and chemical and biological sensors and actuators will be discussed.

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Course website: Carleton Brightspace (https://brightspace.carleton.ca)

Course Outline

The course covers a class of silicon devices, often referred to as microelectromechanical devices or MEMS, and a variety of microsensor devices, both silicon-based and polymer-based. Example devices are chosen with a broad and interdisciplinary interest, ranging from automotive, biomedical, wireless networks, healthcare, and wearable/IoT systems. It is inevitable that engineers and researchers working in different engineering disciplines will encounter microfabricated sensors in some part of their work, however, the standard electrical engineering curriculum focuses on the electrical energy domain and largely neglects the sensor interface with mechanical, optical, thermal, and chemical energy domains, where most sensor responses transpire. This course focuses on the physical design of such microfabricated sensors rather than signal processing, with the primary objective of raising awareness of the capabilities and limitations of semiconductor, emerging materials, thin film, and thick film devices for both commercial and research applications.

Proposed Lecture Topics

1. Fabrication technologies and micromachining techniques.
2. Micro-mechanical structures for MEMS
3. Piezoresistive, capacitive, and piezoelectric sensors.
4. Polymer-based microsensors and polymers in MEMS.
5. Thermal sensors and actuators.
6. Magnetic sensors and actuators.
7. RF MEMS and Optical MEMS.
8. Chemical and biological sensors for health and environmental monitoring

Textbooks and Other Learning Materials

Students are not required to purchase textbooks or other learning materials for this course.

Learning resources will be provided by the instructor through the course webpage. This includes PDF copy of weekly lectures, weekly reading material from reference textbooks and recorded weekly lectures will be shared through the course Brightspace webpage.

Students are encouraged to access these additional learning resources through the library:

1. *Foundations of MEMS*, C. Liu, Pearson Prentice Hall, ISBN: 0131472860 (first edition 2006, library reserve) ISBN: 0132487360 (second edition 2012)

2. *Microsystem Design*, S.D. Senturia, Kluwer Academic Publishers ISBN: 0792372468 (library electronic resource)

3. *Fundamentals of Microfabrication*, M. Madou, CRC Press ISBN: 0849308267 (second edition)

In Term Assessments: Timing and Grading

Assignments (15% X2)	**30%**
Midterm Case Study Presentation	**20%**
Final Project Report	**50%**

- Assignment 1 will be posted in Week 3 whereas Assignment 2 will be posted around Week 9 following the reading week.
- Case study topics will be chosen before Week 7. Students will build upon the selected case study topic to develop final project reports.
- Final Project Report will be submitted individually by students. Instructions on report outline and grading rubric will be available on the course webpage.

The **assignments** will be quantitative - calculating process tolerances, sensor performance, etc. Some knowledge of MATLAB or other calculation and data analysis programs is desired. If you require a Carleton user account and access to certain softwares, please contact ITS (https://carleton.ca/its/all- services/computers/site-licensed-software/).

Assignment and Exam grade postings

All in-term assessment grades will be posted on the Brightspace course website. Students will be notified through regular announcements about assignment posting, grading, and upcoming deadlines. Please check your marks online and report any discrepancies immediately.

Copyright

Advising and Counselling services

a) Engineering Academic Advising

The Engineering Academic Support Service : https://carleton.ca/engineering-design/current-students/undergrad-academic-support/ assists undergraduate engineering students with course selection, registration, and learning support from first-year through to graduation. Academic Advisors Contact : https://carleton.ca/engineering-design/current-students/undergrad-academic-support/undergraduate-advisors/

b) Student Mental Health Service

As a University student you may experience a range of mental health challenges that significantly impact your academic success and overall well-being. Carleton's Wellness Services Navigator https://wellness.carleton.ca/navigator/ is designed to help students connect with mental health and wellness resources. If you need to talk to someone, please reach out for assistance: https://carleton.ca/health/emergencies-and-crisis/.

Learning and Working Environment

The University and all members of the University community share responsibility for ensuring that the University's educational, work and living environments are free from discrimination and harassment. Should you have concerns about harassment or discrimination relating to your age, ancestry, citizenship, colour, creed (religion), disability, ethnic origin, family status, gender expression, gender identity, marital status, place of origin, race, sex (including pregnancy), or sexual orientation, please contact the Department of Equity and Inclusive Communities at equity@carleton.ca
We will strive to create an environment of mutual respect for all through equity, diversity, and inclusion within this course. The space which we work in will be safe for everyone. Please be considerate of everyone's personal beliefs, choices, and opinions.

Academic Integrity and Plagiarism

Please consult the Faculty of Engineering and Design information page about the Academic Integrity policy and our procedures: https://carleton.ca/engineering-design/current-students/fed-academic-integrity.

All students must follow the Academic Integrity Policy when completing course requirements and when interacting with the University. This policy reflects the high academic standards that form the basis for all credentials awarded by the University. When a student is suspected of

violating the Policy, most commonly based on work submitted by the student, an administrative investigation is initiated by the Faculty, with evidence supplied by the faculty member reporting the suspected violation. Violations of the Academic Integrity Policy will result in the assignment of a penalty such as reduced grades, the assignment of an F in a course, a suspension or, expulsion.

One of the main objectives of the Academic Integrity Policy is to ensure that the work you submit is your own. As a result, it is important to write your own solutions when studying and preparing with other students and to avoid plagiarism in your submissions. The University Academic Integrity Policy defines plagiarism as "presenting, whether intentionally or not, the ideas, expression of ideas or work of others as one's own." This includes reproducing or paraphrasing portions of someone else's published or unpublished material, regardless of the source, and presenting these as one's own without proper citation or reference to the original source.

Examples of violations of the policy include, but are not limited to:

- any submission prepared in whole or in part, by someone else;
- using another's data or research findings without appropriate acknowledgement;
- submitting a computer program developed in whole or in part by someone else, with or without modifications, as one's own; and
- failing to acknowledge sources of information through the use of proper citations when using another's work and/or failing to use quotations marks.

Use of Generative Artificial Intelligence (AI)

As our understanding of the uses of AI and its relationship to student work and academic integrity continue to evolve, students are required to discuss their use of AI in any circumstance related to their coursework with the course instructor to ensure it supports the learning goals for the course.
Students can also access resources related to citing Generative AI on the MacOdrum Library website. Additional resources are also available on Carleton's Artificial Intelligence Hub.

Academic Accommodations

Carleton is committed to providing academic accessibility for all individuals. You may need special arrangements to meet your academic obligations during the term. The accommodation request processes, including information about the Academic Consideration Policy for Students in Medical and Other Extenuating Circumstances, are outlined on the Academic Accommodations website (students.carleton.ca/course-outline).

Academic Accommodations for Students with Disabilities: The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or pmc@carleton.ca for a formal evaluation. If you are already registered with the PMC, contact your PMC coordinator to send me your Letter of

Accommodation at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). After requesting accommodation from PMC, meet with me to ensure accommodation arrangements are made. Please consult the PMC website for the deadline to request accommodations for the formally-scheduled exam (if applicable).

Survivors of Sexual Violence: As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: https://carleton.ca/equity/sexual-assault-support-services

Accommodation for Student Activities: Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation will be provided to students who compete or perform at the national or international level. Write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf

Course Schedule

	Topic	Foundations of MEMS (2nd ed)	Microsystems Design	
Week 1:	Introduction to MEMS, Thin film processes	Chapter 1, Chapter 2	Ch 1-3	
Week 2:	Bulk micromachining	Chapter 10	Ch 3-4	
Week 3:	Surface micromachining	Chapter 11, Chapter 12	Ch 3-4	
Week 4:	Mechanical structures at microscale	Chapter 3	Ch 8-9	
Week 5:	Polymers in MEMS: Emerging topics	Review papers, research articles, instructor notes		
Week 6:	MEMS piezoresistive sensors and capacitive sensors	Chapter 4	Ch 6, 19, 20	Assignment 1
Fall break				
Week 7:	Piezoelectric sensors and actuators	Chapter 7	Ch 21	Mid-term Presentation
Week 8:	Thermal sensors and actuators	Chapter 5	Ch 11, 23	
Week 9:	Magnetic sensors and actuators	Chapter 8		
Week 10:	Optical MEMS	Review papers, research articles, instructor notes		
Week 11:	Chemical and Biological sensors	Review papers, research articles, instructor notes		Assignment 2
Week 12:	Final Review	Lecture notes		