

## **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

## **References**

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)

**Note:** PDF copy of weekly lectures, weekly reading material from reference textbooks and recorded weekly lectures will be shared through the course Brightspace webpage.

### **In Term Assessments: Timing and Grading**

<b>Assignments (15% x 2)</b>	<b>30%</b>
<b>Midterm Case Study Presentation</b>	<b>20%</b>
<b>Final exam</b>	<b>50%</b>

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.

The final exam will cover all lectures and additional discussion topics.

The final exam is for evaluation purposes only and will NOT be returned to the student.

The **assignments** will be dominantly quantitative – sensor design optimization, sensor performance, etc, but will also include some descriptive questions on device fabrication. 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**

The materials (including the course outline and any slides, posted notes, videos, labs, project, assignments, quizzes, exams, and solutions) created for this course and posted on this web site are intended for personal use and may not be reproduced or redistributed or posted on any web site without prior written permission from the author(s).

## **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](mailto: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

a) 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> 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.

b) 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.

## Academic Accommodations

You may need special arrangements to meet your academic obligations during the term. For an accommodation request the processes are as follows:

**Pregnancy obligation:** 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. For accommodation regarding a formally-scheduled final exam, you must complete the Pregnancy Accommodation Form ([click here](#)).

**Religious obligation:** 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. For more details click [here](#).

**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](mailto: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**

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