CHM 1102 H: Biosensors and Chemical Sensors

Course Syllabus: Winter 2024

I TEACHING INSTRUCTOR

INSTRUCTOR

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Instructor biography

Professor Michael Thompson obtained his undergraduate degree from the University of Wales, UK and his PhD in analytical chemistry from McMaster University. Following a period as Science Research Council PDF at Swansea University he was appointed Lecturer in Instrumental Analysis at Loughborough University. He then moved to the University of Toronto where he is now Professor of Bioanalytical Chemistry. He is recognized internationally for his pioneering work over many years in the area of research into new biosensor technologies and the surface chemistry of biochemical and biological entities. He has made major contributions to the label-free detection of biological macromolecule interactions and surface behavior of cells using ultra high frequency acoustic wave physics. He has also pioneered the development of anti-fouling surface modification, in particular antithrombogenic and anti-microbial adhesion materials. Thompson has served on the Editorial Boards of a number of major international journals including Analytical Chemistry, The Analyst, Talanta, Analytica Chimica Acta and Biosensors and Bioelectronics. He is currently Editor-in-Chief of the monograph series “Detection Science” for the Royal Society of Chemistry, UK. He has been awarded many prestigious international prizes for his research including The Robert Boyle Gold Medal of the Royal Society of Chemistry, E.W.R. Steacie Award of the Chemical Society of Canada, the Theophilus Redwood Award of the Royal Society of Chemistry, the E.T.S. Walton Award of the Science Foundation of Ireland and the Fisher Scientific Award in Analytical Chemistry of the Chemical Society of Canada. He was made a Fellow of the Royal Society of Canada in 1999.

II COURSE OVERVIEW

COURSE DESCRIPTION:

The notion of a sensor device is common knowledge to all. The range of these structures in modern times is immense, ranging from simple physical measurements such as temperature to complex devices that incorporate human cells in their design. The number of applications is also numerous including industrial processing, pharmaceutical analysis, automotive operation, military technology and environmental signaling to name just a few areas of use. In this course, we introduce the basics of a special branch of sensor technology that deals with the detection of chemicals and biological species, *the chemical and biosensor device.* The course proceeds from a description of overall sensor architecture, to devices types based on electrochemistry, piezoelectric acoustic wave physics and optical science. The course also covers potential applications of these devices especially in the world of medicine. The course is especially interdisciplinary in nature, allowing the student to gain a good understanding of the merging of chemistry with biology, materials science and electronic engineering.

STUDENT LEARNING OUTCOMES:

In this course class members will be able to understand how sensors can be designed for research and applications where detection of biochemical entities are involved. This aim will be achieved by first explaining how biosensors are fabricated including the various physicochemical properties required for this purpose. In particular, students will be able to appreciate the chemistry of sensor transduction processes, compare the performance of various biosensors and from the course have an excellent grounding in the potential applications of biosensors. Such knowledge will be valuable for those who intend to take up a career in bioanalytical chemistry. Finally, the course is highly disciplinary in character which lead the students to a very good understanding of links between chemistry, materials science, biology and medicine.

READINGS:

There is no specific course text book. However, throughout the course an extensive set of review articles, papers and editorials are sent in a timely fashion to class members. In addition, following each lecture, PP slides are provided within 24 hours.

III COURSE ORGANIZATION

- Introduction to biosensor architecture

Types of sensors; components and design; ideal requirements

- Probe attachment

Types of probe – antibodies, nucleic acids, enzymes, receptors; criteria for device surface attachment, introduction to the non-specific adsorption problem

- Methods for probe attachment to surfaces

Adsorption; chemisorption v physisorption; polymer trapping; covalent attachment; film deposition techniques; molecular imprinted polymers and biomimicry.

- Surface characterization

Probe information required; general characteristics of surface analysis, X-ray photoelectron spectroscopy; secondary ion mass spectrometry; Auger spectroscopy; probe techniques such atomic force microscopy

- Electrochemical sensors

Types of devices – potentiometric, amperometric, voltammetric; ion selective electrodes; physics of field effect transistor technology - ISFETS, IMMUNOFETS; history and design of the glucose electrode; nucleic acid –based electrochemical sensing

- Acoustic wave devices

The phenomenon of piezoelectricity; operation of devices in air; bulk acoustic wave devices as chemical sensors; the Sauerbrey response equation; propagation of acoustic waves in fluids; other devices – surface acoustic wave, shear horizontal wave, surface transverse wave

- Optical and electromagnetic radiation-based devices

Sources of radiation for sensors; laser technology; optical components; fiber optic-based systems for sensing; intrinsic versus extrinsic sensing mechanisms; evanescent wave technology; the phenomenon of surface plasmon resonance; design of the SPR experiment for bio-sensing; other types such interferometry

IV EVALUATION/GRADING SCHEME

Peer Assignment =50% total grade
Final Course Essay = 50% total grade – due on the last day of the semester

Note: if an unexpected technical issue occurs with a university system (e.g., Quercus services, network outage) that affects availability or functionality, it may be necessary to revise the timing or weighting of the assessments.

V COURSE POLICIES

Each member of this course is expected to maintain a:

(i) professional and respectful attitude during all course activities, including classes, laboratories, tutorials and online activity.
(ii) personal calendar/schedule/organizer to ensure that all course activities are completed, and due dates are met.
(iii) collection of notes recorded independently based on concepts covered in course activities (students registered with Accessibility Services requiring a class note-taker will have access to this accommodation)
(iv) familiarity with the university policy on Academic Integrity (overleaf)

The University of Toronto is committed to equity, human rights and respect for diversity. All members of the learning environment in this course should strive to create an atmosphere of mutual respect where all members of our community can express themselves, engage with each other, and respect one another's differences. As a Course Instructor, I will neither condone nor tolerate behavior that undermines the dignity or self-esteem of any individual in this course and wish to be alerted to any attempt to create an intimidating or hostile environment. It is our collective responsibility to create a space that is inclusive and welcomes discussion. Discrimination, harassment and hate speech will not be tolerated. If you have any questions, comments, or concerns, we encourage you to reach out to the staff in our Equity Offices.

- Communication with instructor (e.g., I will respond to email within 24 hrs. on weekdays).

- Privacy language and appropriate use of course materials: https://teaching.utoronto.ca/ed-tech/audio-video/sample-statements/

- Policy for late assignment submissions (e.g., x% will be deducted daily).

- Policy for reweighting due to missed pieces of academic work.
- Submission methods (e.g., use Quercus only).
- Process for requesting re-grading of course work.
- Process for signaling course absences and requesting make-up tests or exams, if applicable.

VI TECHNOLOGY REQUIREMENTS

- Specific guidance from the U of T Vice-Provost, Students regarding student technology requirements is available here: https://www.viceprovoststudents.utoronto.ca/covid-19/tech-requirements-online-learning/
- Advice for students more broadly regarding online learning is available here: https://onlinelearning.utoronto.ca/getting-ready-for-online/
- This course requires the use of computers, and technical issues are possible. When working on a piece of academic work, students are responsible for scheduling enough time to allow for reasonable delays due to technical difficulties to be overcome, so such issues will not be acceptable grounds for deadline extension. Particularly, maintaining an up-to-date independent backup copy of your work is strongly recommended to guard against hard-drive failures, corrupted files, lost computers, etc.

VII INSTITUTIONAL POLICIES & SUPPORT

AI

The use of generative artificial intelligence (AI) tools and apps is strictly prohibited in all course assignments unless explicitly stated otherwise by the instructor in this course. This includes ChatGPT and other AI writing and coding assistants. Use of generative AI in this course may be considered as use of an unauthorized aid, which is a form of cheating. This course policy is designed to promote your learning and intellectual development and to help you reach the course learning outcomes

ACADEMIC INTEGRITY

Academic integrity is essential to the pursuit of learning and scholarship in a university, and to ensuring that a degree from the University of Toronto is a strong signal of each student's individual academic achievement. As a result, the University

treats cases of cheating and plagiarism very seriously. The University of Toronto's Code of Behaviour on Academic Matters (governingcouncil.utoronto.ca/secretariat/policies/code-behaviour-academic-matters-july-1-2019) outlines the behaviours that constitute academic dishonesty and the processes for addressing academic offences. Potential offences include, but are not limited to:

In virtual laboratory reports:

1. Using someone else's ideas or words without appropriate acknowledgement.
2. Submitting your own work in more than one course without the permission of the instructor.
3. Making up sources or facts.
4. Obtaining or providing unauthorized assistance on any report. **Please note that the use of websites (such as Chegg.com or the course discussion board) to post virtual laboratory report material/questions or to post/access answers to questions is an academic offence under the University of Toronto's Code of Behaviour on Academic Matters. Alleged instances of this nature are forwarded to the Faculty of Arts & Science Student Academic Integrity office.**

On quizzes and term tests:

1. Using or possessing unauthorized aids. **Please note that the use of websites (such as Chegg.com or the course discussion board) to post quiz/term test questions or to post/access answers to questions is an academic offence under the University of Toronto's Code of Behaviour on Academic Matters. Alleged instances of this nature are forwarded to the Faculty of Arts & Science Student Academic Integrity office.**
2. Looking at someone else's answers or collaborating/discussing answers during a quiz or term test.
3. Misrepresenting your identity.

In general academic work:

1. Falsifying institutional documents or grades.
2. Falsifying or altering any documentation required by the University.

All suspected cases of academic dishonesty will be investigated following procedures outlined in the Code of Behaviour on Academic Matters. If you have questions or concerns about what constitutes appropriate academic behaviour or appropriate research and citation methods, you are expected to seek out additional information on academic integrity from your instructor or from other institutional resources (see www.academicintegrity.utoronto.ca/).

COPYRIGHT
Sample statements for instructor recording of online courses are available here: https://teaching.utoronto.ca/resources/recording-of-lectures-and-class-sessions/

If a student wishes to copy or reproduce class presentations, course notes or other similar materials provided by instructors, he or she must obtain the instructor's written consent beforehand. Otherwise, all such reproduction is an infringement of copyright and is absolutely prohibited. More information regarding this is available here: https://teaching.utoronto.ca/ed-tech/audio-video/copyright-considerations/

ACCESSIBILITY NEEDS
Students with diverse learning styles and needs are welcome in this course. The University of Toronto is committed to accessibility: if you require accommodations for a disability, or have any other accessibility concerns about the course, please contact Accessibility Services as soon as possible.

ACCOMMODATIONS FOR RELIGIOUS OBSERVANCES
Following the University's policies, reasonable accommodations will be made for students who observe religious holy days that coincide with the due date/time of an assignment, tutorial, class or laboratory session. Students must inform the instructor **before** the session/assignment date to arrange accommodations.

ADDITIONAL SERVICES & SUPPORT
The following are some important links to help you with academic and/or technical service and support:

- General student services and resources at Student Life
- School of Graduate Studies' Policies and Guidelines
- Full library service and resources on conducting online research through University of Toronto

Libraries University Libraries Research

- Resources on academic support from the Academic Success Centre
- Learner support at the Writing Centre
- Information for Technical Support/Quercus Support

ACKNOWLEDGEMENT OF TRADITIONAL LANDS
We wish to acknowledge this land on which the University of Toronto operates. For thousands of years, it has been the traditional land of the Huron-Wendat, the Seneca and, most recently, the Mississaugas of the Credit River. Today, this meeting place is still the home to many Indigenous people from across Turtle Island and we are grateful to have the opportunity to work on this land.