COURSE: NE 476 / ECE 634 (Winter 2027)

COURSE TITLE: **Organic Electronics**

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DESCRIPTION:

The course gives an overview of organic electronic and optoelectronic devices. It begins with a review of electronic structure of single organic molecules as a guide to the electronic behaviour of organic aggregates. Various relevant material phenomena are reviewed; including topics from photo-physics (absorption and emission of light, excited states, radiative and non-radiative transitions), intermolecular charge transport mechanisms (hopping, disorder), charge injection and transport models, and energy transfer processes. Their applications in light emitting devices, solar cells, thin film transistors, photodetector and imaging photoreceptors, etc. are discussed. Aspects related to device fabrication and patterning may also be addressed.

COURSE/TEACHING OBJECTIVES:

This course will help students with no or limited prior background in the field to:

- Acquire a general background in the field of organic electronics and optoelectronics, basic theory, applications, challenges, recent developments, etc.
- Know and understand relevant fundamental scientific theory (qualitatively), and its relationship to organic semiconductor material properties, device working mechanisms, and general device design rules.
- Become familiar with relevant terminology, and able to read and understand scientific literature in the field.
- NE476 only: Become able to conduct a simple design analysis of a certain organic electronic device.
- ECE634 only: Become able to survey and analyze research papers on certain relevant topics in the field

SYLLABUS:

01. Introduction to OLEDs:
    OLED Operation Mechanism, injection, transport and emission of light. Organic heterojunction. General comparison of inorganic versus organic devices
02. Electronic Structure of Organic Molecules
    Atomic and Molecular Orbitals, LCAO, Bonding and anti-bondig orbitals, Orbital hybridization, HOMO and LUMO levels, Conjugated Molecules
03. Photophysics of Organic Molecules
    Excited states: (Absorption and emission, Singlet and triplet states), Rates of electronic transitions, Transition moment, Frank Condon Principle, Radiative and non-radiative transitions, Excited state kinetics
04. Exciton Processes in Organic Solids
    The Solid State: (Bonding, states of matter, amorphous & crystalline states), Excitons, Forester and Dexter energy transfer, Exciton quenching processes
05. Electronic Conduction in Organic Solids
    Conductivity: (carrier concentration versus mobility), Carrier generation, Hopping transport, Mobility measurements, Traps.
06. Aspects of OLED Physics and Technology
    Charge injection from metal contacts, Charge transport and device characteristics, Exciton formation and luminescence, OLED Efficiency, Stability and aging, RGB patterning approaches.
07. Organic Light Harvesting Devices
    Photoreceptor Devices, Photodetector Devices, Photovoltaic Devices: General background, device operation mechanism and characteristics, important phenomena, current challenges, recent developments
08. Organic Electronic Materials & Organic TFTs
    Small molecule and polymer materials for OEs. Hole and electron transport. Molecular design rules for mobility and chemical stability. OTFT operation mechanism and characteristics, important phenomena, recent developments
09. Selected Topics in Organic Electronics (if time permits)
    Quantum-dot OLEDs. etc.

TEXTBOOK:

No textbook required. Lecture notes and handouts will be provided.

GENERAL REFERNCES

- "Electronic Processes of Organic Crystals and Polymers" , Pope & Swenberg, Oxford University press, 2nd edition (1999).
- "Essentials of Molecular Photochemistry" , Gilbert & Baggott, CRC Press, 1991.
- "Organic Semiconductors" H. Meier, Verlag Chemie GmbH, 1974
- "Physics of Organic Semiconductors" Wolfgang Brütting, John Wiley & Sons Canada; 1 edition (2005)
- "Organic Electronics: Materials, Manufacturing, and Applications" , Hagen Klauk, John Wiley & Sons; 1st edition (2006)
- "Electrical transport in solids : with particular reference to organic semiconductors", Kao, Pergamon Press; 1st edition (1981).

MARKING SCHEME

Different marking schemes will be used for ECE634 and NE476:

NE476:

- 20% Quizzes*
  Two quizzes, ~15-20 minutes each, will be held during regular lecture time on **Feb 8 & Mar 29, 2027.** The weights of the quizzes will be one of the following based on what works best for each person: 5%+15%, 15%+5%.
- 30% Midterm Exam
  The exam will be ~60 minutes long and will be held during regular lecture time on **Mar 1, 2027.**
- 50% Final Exam
  The Final Exam will be held during UW regular final exam period.
- 10% Optional Device Analysis Assignment
  NE476 students have the option to do an assignment of scope as described on page 4. For students pursuing this option the combined weights of the midterm and final exams will be 70% (instead of 80%), with 30% and 40% or 25% and 45%, allocated to the midterm and final exams, respectively, based on what works best for each person. Students must confirm their plans to exercise this option no later than **March 19th** via an email to the TA. Students who have sent that email must proceed with the option (i.e. cannot opt out later).

  IMPORTANT NOTE FOR NE 476 STUDENTS CHOOSING TO DO THE OPTIONAL ASSIGNMENT:
  To pass the course, students taking the is option must obtain a total of **at least 45/90** in the two quizzes, midterm and final exam combined. Otherwise, that total will be the mark they will get in this course.

ECE634:

- 20% Quizzes*
  Two quizzes, ~15-20 minutes each, will be held during regular lecture time on **Feb 8 & Mar 29, 2027.** The weights of the quizzes will be one of the following based on what works best for each person: 5%+15%, 15%+5%.
- 20% Midterm Exam
  The exam will be ~60 minutes long and will be held during regular lecture time on **Mar 1, 2027.**
- 15% Literature Review Project
  See page 5 for more details.
- 45% Final Written Exam.
  The Final Exam will be held during UW regular final exam period.

  IMPORTANT NOTE FOR ECE 634 STUDENTS: In addition to satisfying ECE minimum grade requirements for passing graduate courses, ECE634 students must also obtain a total of **at least 51/85** in the two quizzes, midterm and final exam combined in order to pass this course.

* IMPORTANT NOTE FOR NE476 and ECE634 STUDENTS: A student who misses a quiz must contact the instructor within 24 hrs of the missed quiz in order to schedule a 15-20 min oral quiz with the instructor. The scope of the oral quiz will be similar to that of the missed written quiz but the questions (including their number) may be different. The oral quiz must be completed within 1 week of the original quiz date. The oral quiz must be conducted in-person and may be recorded for the purpose of record-keeping. Failing to meet this requirement will lead to a mark of zero on the missed quiz. Exceptions to this rule may be made at the instructor's discretion in cases when a quiz is missed due to extenuating circumstances with appropriate verification (e.g. through AccessAbilityServices accommodation or other forms of documentation).

COURSE WEBSITE:

A course homepage is available on LEARN. It will contain copies of lecture slides and notes. The slides and notes will be uploaded weekly prior to each lecture. The site also contains a copy of this course outline. It will also be uploaded with any important updates, etc.

CLASS ATTENDANCE:

Additional material and details - beyond those captured in the posted lecture slides and notes – will be covered during lectures. Regular class attendance is important for doing well in this course.

LECTURES:

Regular time: 10:00-11:20 on Mondays and 8:30-9:50 on Fridays in RCH-305

Extra lecture: **4:00-5:20PM on Tuesday, Feb 9 in RCH-105** (in lieu of the class slot used for the midterm)

TENTATIVE SCHEDULE:

A tentative schedule is shown below. The instructor reserves the right to change the outline and/or the schedule as needed.

Week No.	Main Subject/Topics Covered during Lecture
1	*>>>Course introduction* 01.Introduction to OLEDs
2	02.Electronic Structure of Organic Molecules
3	03.Photophysics of Organic Molecules
4	03.Photophysics of Organic Molecules
5	04.Excitonic Processes in Organic Solids *>>> Quiz 1*
6	05.Electronic Conduction in Organic Solids
7	06. OLED Physics and Technology *>>> Midterm*
8	06. OLED Physics and Technology
9	07.Organic Light Harvesting devices
10	07.Organic Light Harvesting devices
11	08. Organic Electronic Materials & OTFTs *>>> Quiz 2*
12	08. Organic Electronic Materials & OTFTs >>> NE *476 Device Analysis Assignment* *>>> ECE 634 Oral Presentations & Written Critiques*

NE 476 DEVICE ANALYSIS ASSIGNMENT - OPTIONAL:

- Each student will choose and read a scientific paper in the area of organic electronics that focuses on improving the performance of a certain organic electronic device.

- Students will prepare a 5 minute PowerPoint presentation in which they will a) describe the device structure and the different layers it includes using an appropriate energy band diagram, b) explain the operation mechanism of the device, pointing to the role of each layer in device operation mechanism, and c) indicate the factors behind the performance improvement. In addition, students must include a final slide titled **"Connection to Course Material"**, in which they identify at least one specific concept covered in class and explain how it relates to their selected research paper and how this connection helps them better understand the device operation or performance discussed in the paper.

- Students will record the presentations and submit them (as .mp4) on Learn anytime until the last day of classes **(April 12, 2027).** In addition to the slides, the recording must show the student's face delivering the presentation.

- The instructor may provide some papers for students to select from. Students however are encouraged to choose papers from outside of the list suggested by the instructor. In all cases students must seek the TA's approval of their chosen papers to make sure they are suitable and have not been taken by other students (first come first serve basis) **by Apr 2, 2027**

- In general, in order to be acceptable, a paper must meet the following conditions:
    a. Must be published in an ISI-indexed journal
    b. Must have received >20 citations (papers published in the last two years are exempted from this requirement)
    c. Must be at least 4 journal pages long (excluding references). Selecting much longer papers is discouraged.

- **Students electing to complete this assignment must confirm their plans to pursue this option no later than March 19th 2027 via an email to the TA.**

ECE634 LITERATURE REVIEW:

- Each student will conduct an in-depth, individually conducted review of at least 2 scientific papers on one topic relevant to organic electronics. The students will give **an oral presentation and write a written critique** on the papers

- The topic and papers are to be selected by the student, but must be approved by the course instructor. The final choice of topic and papers must be confirmed to the instructor by email and approved by the instructor **by the end of week 8 of the term (i.e. March 12, 2027).**

- In general, in order to be acceptable, each selected paper must meet the following conditions:
  - Must be a peer-reviewed research article on a topic in the field of organic electronic materials and devices
  - Must be published within the last 7 years in an ISI-indexed journal with an impact factor >5.0
  - Must have received >10 citations (papers published in the last two years are exempted from this requirement)
  - Must be at least 5 journal pages long (excluding references)

- PDF copies of the confirmed papers (i.e. after they have already been approved by the instructor earlier) should be emailed to the instructor **no later than the end of week 8 of the term**. The following file name format must be used for the PDFs: **YourLastName_FirstAuthorLastName_YearPublished.pdf**

- Marking Scheme:
  - Oral Presentation: 9% of total course grade
  - Participation in the Q&A sessions of the other ECE634 students presentations: 1% of total course grade
  - Written Critique: 5% of total course grade

- **Oral Presentation:**
  - The presentation will typically be 25-30 minutes long including time for Q&A. **The presentations will be scheduled (tentatively) for weeks 11 & 12 of the term.** The presentations are normally scheduled during regular class hours, however, depending on the number of students taking the course (and hence the number of presentations), they may have to be scheduled outside of regular class hours. The exact dates and times (as well as presentation length) will depend on the final number of students enrolled in the course and therefore will be confirmed later by Week 7 of the term.

  d. A copy of presentation slides should be uploaded to the designated Dropbox on Learn **by 8:00 am on the day of your presentation.** The following file name format must be used for your slides file: **YourLastName.pdf.** The slides will be uploaded on LEARN and made available to all students in the class.

  e. In general, your review, and hence your presentation, should include the following elements:
    i. Background: This part should give some introduction to the general topic that the selected papers represent. This part can be for all papers combined, or divided to serve as a separate background for each paper, as may be appropriate
    ii. Results & Discussion: A brief outline of the important results or findings in each paper
    iii. Conclusions: A summary of the main conclusions of each paper

  f. Marking: The following general and approximate marking scheme will be used:

  Background (2/9); Results & Discussion (3/9); Summary of Conclusions (1/9); General Presentation (1/9); Answers to questions (2/9).

  Note: The variety in the nature of the different topics may require customizing the marking scheme to make it more relevant to the individual topics. Therefore, the actual marking scheme may differ from this one.

- **Written Critique:**

  a. The critique will be 2 single-spaced pages max (+ a title page, that shows your name, the main topic covered by the papers, and the full bibliographic information of the papers) written in font size 12, and will include two parts; 1) a ~¼ - ½ page overview for each paper, each in a separate section, that summarizes the main findings and conclusions of the paper, and 2) a personal critique section that presents your own views of the strengths and/or weaknesses of the papers, with appropriate justifications, and areas where results or conclusions of the papers may agree or disagree with each other.

  b. The critique **is due on April 12, 2027.** The document should be submitted by uploading it to the designated Dropbox folder on Learn. **Turnitin® software will be used in assessing the originality of the writing.**

  c. Marking: The following general and approximate marking scheme will be used: Part 1 (2.5/5); Part 2 (2.5/5)
  Note: The variety in the nature of the different topics may require customizing the marking scheme to make it more relevant to the individual topics. Therefore, the actual marking scheme may differ from this one.

Important information & policies:

Academic integrity: In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. [Check the Office of Academic Integrity for more information.]

Grievance: A student who believes that a decision affecting some aspect of their university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4. When in doubt, please be certain to contact the department's administrative assistant who will provide further assistance.

Discipline: A student is expected to know what constitutes academic integrity to avoid committing an academic offence, and to take responsibility for their actions. [Check the Office of Academic Integrity for more information.] A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate associate dean. For information on categories of offences and types of penalties, students should refer to Policy 71, Student Discipline. For typical penalties, check Guidelines for the Assessment of Penalties.

Appeals: A decision made or penalty imposed under Policy 70, Student Petitions and Grievances (other than a petition) or Policy 71, Student Discipline may be appealed if there is a ground. A student who believes they have a ground for an appeal should refer to Policy 72, Student Appeals.

Note for students with disabilities: AccessAbility Services, located in Needles Hall, Room 1401, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with AccessAbility Services at the beginning of each academic term.

Short-term absences: Short-term absences cannot be used for graded course components that involve a formally scheduled presentation or are part of a symposium, colloquium, or showcase. They also cannot be used for graded components requiring live, in-person group work, such as peer review workshops. These assignments involve singular events that cannot be rescheduled and may depend on the participation of classmates during class time. It is the student's responsibility to review the deadlines for these in-person assessments at the start of the term and to contact the instructor within the first two weeks of class if they anticipate a conflict with a scheduled event. This policy does not override university-wide policies (e.g., National Day for Truth and Reconciliation), absences due to religious observance, documented extenuating circumstances, accommodations through AccessAbility Services, or VOC requirements.

Turnitin.com: Text matching software (Turnitin®) may be used to screen submissions, assignments and other deliverables in this course. Turnitin® is used to verify that all materials and sources in assignments are documented. Students' submissions are stored on a U.S. server, therefore students must be given an alternative (e.g., scaffolded assignment or annotated bibliography), if they are concerned about their privacy and/or security. Students will be given due notice, in the first week of the term and/or at the time assignment details are provided, about arrangements and alternatives for the use of Turnitin in this course.