Spring 2025

University of Illinois at Urbana-Champaign

ECE 498: Semiconductor Innovations: Leap Ahead Technologies

The course instructor is **Prof. John Dallesasse**

The course structure consists of two lecture/discussion meetings per week. Final course grades are based on the distribution of total points accumulated on the final project, two exams, in-class activities, and assigned homeworks, as described in the section on grading criteria.

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Prerequisite: ECE 340

3 HOURS

Course Goals

This course aims to prepare students to interface with emerging technologies throughout their career in industry or academia.

Learning Outcomes:

- **LO1:** Students will be able to identify and assess current and past commercial leap ahead technologies including transistors and vertical-cavity surface-emitting lasers (VCSELs).
- **LO2:** Students will be able to analyze wide-bandgap semiconductor devices with applications in power electronics and photonics.
- **LO3:** Students will be able to conceptualize, critique, and compare photonic technologies including silicon photonics, photonic integrated circuits, and electro-optic systems.
- **LO4:** Students will be able to conceptualize, critique, and compare wafer and chiplet bonding techniques and applications including high temperature direct bonding, plasma-activated bonding, and metal-assisted bonding.
- **LO5:** Students will be able to identify and propose commercial leap ahead solutions to current technical problems.

Instructor & Office Hours

Instructor: Prof. John Dallesasse
TA: Leah Espenhahn

Course Website: Canvas

Office Hours: Office hours will be held regularly as listed below. Individual appointments may be made outside the scheduled hours as needed, either by contacting the instructor before/after class or via email.

Name	Office Hour Location	Office Hour Time	Email
Prof. John Dallesasse	MNTL 2114	TBA	Jdallesa@illinois.edu
Leah Espenhahn	TBA	TBA	Leahe2@illinois.edu

Required and Reference Textbooks

Required Texts
Class notes and reading materials will be distributed electronically through the course website.

Reference Textbooks (Not Required)
For refreshing basic semiconductor theory:

- C. Kittel, Introduction to solid state physics (any edition), John Wiley
- Free online textbook, see: https://truenano.com/PSD20/contents/contents.htm, Prof. Bart Van Zeghbroeck, University of Colorado

Course Expectations

Prerequisites: ECE 340 or equivalent.

Class Etiquette: While attendance itself is not recorded, there will be frequent in-class activities that require your attendance and participation. If you are unable to attend a class, follow the course policy on absences. There is a strong correlation between completing the required work satisfactorily and your grade – don't miss an assignment as a "0" is difficult to overcome. For in-person classes electronic devices can be a source of distraction to you and for the fellow students around you so please be respectful and don't use them in class. Uploading or downloading material from 3rd party sites will be considered an academic integrity violation.

Assignments, Exams, & Grading Criteria

In-Class Assignments: While attendance itself is not recorded, there will be frequent in-class activities that require your attendance and participation. If you are unable to attend a class, follow the course policy on absences.

Assignments: Out of class/ homework assignments will be regularly assigned, with deadlines before a class period. The assignments are designed to reinforce understanding of key concepts, to build skills in extending conceptual knowledge in novel ways, or to prepare students for discussions around key topics. In some cases, completion of a homework problem will require independent study of topics related to but not necessarily covered in class. These are designed to advance the skills needed as a practicing engineer or researcher, where encountering new problems is both normal and common.

Exams: This course will have two, 1-hour exams during class time. The exams will be cumulative and closed book. One hand-written 8.5" X 11" double-sided formula sheet may be brought in for the first exam, and two 8.5" X 11" double-sided formula sheets may be brought in for the second exam. A simple scientific calculator is allowed, but additional formulae must not be stored in the calculator, and it must not have networking capability. You will not be allowed to use your cell phone's calculator function during quizzes or exams. The format of your exam solutions should be the same as that used for the homework assignments: units must be shown explicitly, your answer must be circled, and your work must be readable. Numerical answers should contain an appropriate number of significant figures.

Term Project: There will be a group term project [TP] and presentation on a topic chosen from provided examples, or as arranged with the instructor. It will consist of a white paper proposal and 20-minute presentation on the research proposal. This project will be scaffolded across the semester, with opportunities to gain experience presenting and review drafts prior to the final submission and presentation.

Grading Criteria: Your grade in this course is based primarily on your scores on the in and out of class assignments, the exams, and the final project.

In-Class Assignments & Participation 10%
Before-Class Assignments 10%
Exams.....40%
Term Project.....40%

Total 100%

Course Policy on Absences

If you miss an assignment or exam the following procedures apply:

1) Do not come to class if you feel ill. Email the instructor as soon as possible if missing an in-class assignment or exam.
2) Absences for specific university-sponsored events or religious observances outlined in the student code that impact your ability to complete an assignment or take an exam must be pre-arranged with the course instructor. Upon verification that the excuse is valid and complies with the UIUC Student Code, the course instructor will issue an excused absence, extended deadline, or alternative assignment on a case-by-case basis.
3) In the event of severe illness, you must receive an Excused Absence from the Undergraduate College Office, Room 207 Engineering Hall, indicating what work you have missed and the reason for the absence. This absence must be approved by the Office of the Dean of Students (Emergency Dean) for an excuse due to personal illness, family emergencies, or other uncontrollable circumstances. The office may be reached at 333-0050.

For missed classes or exams, e-mail the excused absence letter to the course director Prof. Dallesasse and your instructor as soon as possible after you return.

Scores on exams missed due to excused absences will not be made up if the exam cannot be taken within a reasonable time after the regular exam. Your grade will be determined based on the average of the grades that you have completed. Specifically, the average of your completed scores will be used to determine the total, homework or exam score and the final total score.

Work missed due to an unexcused absence will be counted as a 0.

Grainger College of Engineering Syllabus Statements:

The following statements reflect the policies of the College and have been provided for inclusion in course syllabi:

Emergency Response Recommendations
Emergency response recommendations can be found on the Division of Public Safety website. I encourage you to review this website and the campus building floor plans website within the first 10 days of class. http://police.illinois.edu/emergency-preparedness/building-emergency-action-plans/.

Academic Integrity
The University of Illinois at Urbana-Champaign Student Code should also be considered as a part of this syllabus. Students should pay particular attention to Article 1, Part 4: Academic Integrity. Read the Code at the following URL: http://studentcode.illinois.edu/.

Academic dishonesty will result in a sanction proportionate to the severity of the infraction, with possible sanctions described in 1-404 of the Student Code. Every student is expected to review and abide by the Academic Integrity Policy as defined in the Student Code. As a student it is your responsibility to refrain from infractions of academic integrity and from conduct that aids others in such infractions. A short guide to academic integrity issues is provided by the provost office. Ignorance of these policies is not an excuse for any academic dishonesty. It is your responsibility to read this policy to avoid any misunderstanding. Do not hesitate to ask the instructor(s) if you are ever in doubt about what constitutes plagiarism, cheating, or any other breach of academic integrity.

In this course you are expected to produce your own work in all assignments. Where appropriate written assignments will be submitted through a plagiarism checker, a software tool that compares your writing against a large database as well as to the work of your current classmates and previously submitted assignments. Assignments with close matches to other work will be flagged and investigated.

Unless otherwise informed, the use of calculators or electronic devices (cell phones or others) will not be allowed during examinations. If you are found using one, it will be investigated as potential cheating.

Anti-Racism and Inclusivity Statement
The Grainger College of Engineering is committed to the creation of an anti-racist, inclusive community that welcomes diversity along a number of dimensions, including, but not limited to, race, ethnicity and national origins, gender and gender identity, sexuality, disability status, class, age, or religious beliefs. The College recognizes that we are learning together in the midst of the Black Lives Matter movement, that Black, Hispanic, and Indigenous voices and contributions have largely either been excluded from, or not recognized in, science and engineering, and that both overt racism and micro-aggressions threaten the well-being of our students and our university community.

The effectiveness of this course is dependent upon each of us to create a safe and encouraging learning environment that allows for the open exchange of ideas while also ensuring equitable opportunities and respect for all of us. Everyone is expected to help establish and maintain an environment where students, staff, and faculty can contribute without fear of personal ridicule, or intolerant or offensive language. If you witness or experience racism, discrimination, micro-aggressions, or other offensive behavior, you are encouraged to bring this to the attention of the course director if you feel comfortable. You can also report these behaviors to the Bias Assessment and Response Team (BART) (https://bart.illinois.edu/**).** Based on your report, BART members will follow up and reach out to students to make sure they have the support they need to be healthy and safe. If the reported behavior also violates university policy, staff in the Office for Student Conflict Resolution may respond as well and will take appropriate action.

Disability-Related Accommodations
To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor and the Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES, you may visit 1207 S. Oak St., Champaign, call 333-4603, e-mail disability@illinois.edu or go to https://www.disability.illinois.edu. If you are concerned you have a disability-related condition that is impacting your academic progress, there are academic screening appointments available that can help diagnosis a previously undiagnosed disability. You may access these by visiting the DRES website and selecting "Request an Academic Screening" at the bottom of the page.

Family Educational Rights and Privacy Act (FERPA)
Any student who has suppressed their directory information pursuant to Family Educational Rights and Privacy Act (FERPA) should self-identify to the instructor to ensure protection of the privacy of their attendance in this course. See https://registrar.illinois.edu/academic-records/ferpa/ for more information on FERPA.

Religious Observances
Illinois law requires the University to reasonably accommodate its students' religious beliefs, observances, and practices in regard to admissions, class attendance, and the scheduling of examinations and work requirements. You should examine this syllabus at the beginning of the semester for potential conflicts between course deadlines and any of your religious observances. If a conflict exists, you should notify your instructor of the conflict and follow the procedure at https://odos.illinois.edu/community-of-care/resources/students/religious-observances/ to request appropriate accommodations. This should be done in the first two weeks of classes.

Sexual Misconduct Reporting Obligation
The University of Illinois is committed to combating sexual misconduct. Faculty and staff members are required to report any instances of sexual misconduct to the University's Title IX Office. In turn, an individual with the Title IX Office will provide information about rights and options, including accommodations, support services, the campus disciplinary process, and law enforcement options.
A list of the designated University employees who, as counselors, confidential advisors, and medical professionals, do not have this reporting responsibility and can maintain confidentiality, can be found here: wecare.illinois.edu/resources/students/#confidential.

Other information about resources and reporting is available here: wecare.illinois.edu.

Couse Schedule and Outline

Class #	Topic	Before Class Assignment	In Class Assignment
1	Intro to course, discussion on what is commercial leap ahead (CLA)?	Submit form to determine group assignments	Form groups & complete group identity form [TP1]
2	Case Study 1: Transistor history, theory, fab		How to read/annotate technical paper
3	Case Study 1: Transistor history, theory, fab	Read & annotate assigned paper	Jigsaw papers
4	Case Study 2: VCSEL history, theory, fab		Discuss additional examples of CLA tech
5	Case Study 2: VCSEL history, theory, fab	Create timeline for selected technology	Small-group presentations of timeline
6	What's next: Current drivers of technological advancements		Groups discuss potential driver(s) of project area [TP2.1]
7	Intro to WBG semiconductors		Groups select driver(s) of project area [TP2.2]
8	WBG transistors	Find & annotate 3+ papers potentially relevant to project area [TP3.1]	Groups discuss papers & key takeaways [TP3.2]
9	WBG transistors (TFT)		WBG Discussion
10	WBG power electronics (rectifiers, power switches)	Find & annotate 3+ papers relevant to project area [TP 5.1]	Groups discuss papers [TP 5.2]
11	WBG photonics (LEDs, lasers, photodetectors)	WBG transistors & power technical calculation practice	
12	WBG PICs	Read & annotate assigned WBG paper	Jigsaw papers
13	Intro to Ultra-Wide Bandgap Semiconductors	WBG photonic technical practice	UWBG Discussion
14	Exam 1		
15	Silicon photonics		Exam Review
16	Pockels electro-optic effect		Electro-optics discussion
17	Electro-optic modulators (Q-switch) & deflectors	Project Introduction Draft [TP 6.1]	Introduction review & feedback [TP 6.2]
18	Electro-optic field sensors		Groups reflection on feedback [TP 6.3]
19	Quantum-confined Stark effect		Groups create project outline [TP 7]
20	Electro-absorption modulator (Ge/SiGe QCSE)	Read & annotate assigned electro-optic paper	Jigsaw papers
21	Integrated Photonics Systems (passive components, tuning structures)		
22	Intro to heterogeneous integration	Electro-optics technical practice	Groups select topic from class to present on

23	Metal-assisted bonding, High-temp direct bonding	Create 10-minute presentation (for non-technical audience) on topic	Present introduction to topic for non-technical audience
24	Plasma-activated bonding	(Optional) Project Draft	Present introduction to topic for non-technical audience
25	Chiplet bonding, bonding on interposers	Read & annotate assigned bonding paper	Jigsaw papers
26	3D Stacking (DRAM)	Bonding technical practice	Review
27	Exam 2		
Final Exam Period	Present Final Proposal [TP9]	Submit Final Proposal Paper [TP8]	