

ECH 6937: Electron Transport Phenomena in Semiconductors
Class Periods: Monday, Wednesday, Friday, Period 4 (10:40 – 11:30 am)
Class Location: FLI0121 (Keene-Flint Hall)
Academic Term: Spring 2022

Instructor

Prof. Charles Hages
Assistant Professor, Chemical Engineering Department, University of Florida
Office: ChE Room 417
E-mail address: c.hages@ufl.edu
Office telephone: 352-294-7002
Office hours: TBD
Web site: UF course Canvas web site

Course Description

Application of fundamental Chemical Engineering concepts of transport phenomena (e.g. fluid, heat, and mass) to the principles of electron transport in solid-state semiconductors. Special emphasis will be placed in relating electronic transport to fundamental chemical and material properties. An overview of basic semiconductor physics will be given, followed detailed derivation of the principles of electron drift and diffusion. Relevant optoelectronic characterization techniques to probe electron transport will be discussed. Transient simulation of electron transport will be incorporated throughout the course using Python

Course Pre-Requisites / Co-Requisites

N/A

Course Objectives

Following this course, students will be able to understand and interpret energy band diagrams for semiconductors; apply fundamental transport concepts relating to diffusion to electrons in semiconductors; apply fundamental transport concepts relating to drift for charged particles in an electric field; understand optoelectronic characterization techniques of semiconductors; and utilize numerical methods to solve and visualize the solution to coupled, non-linear partial differential equations using software.

Materials and Supply Fees

N/A

Required Textbooks and Software

- *Text:* Course notes are developed by the instructor – no required text
- *Software:* Python. Can be installed for free using the Anaconda package:
<https://www.anaconda.com/products/individual>

Recommended Materials

- Advanced Semiconductor Fundamentals
- Robert F. Pierret
- Aug. 2002; Second Edition
- ISBN: 013061792X

Course Schedule (Tentative)

Part (1), Introduction:

- i. Introduction to Materials: What is a semiconductor; The Atom; Molecular Orbital Theory
- ii. Mathematical Derivations: Into to Quantum Mechanics; Particle in a box; Energy Band Theory
- iii. Semiconductor Fundamentals: Energy Band Structure for Semiconductors; 3D Materials; Density of States; Electron Occupation (Fermi Function); Equilibrium Distribution and Occupation of Electrons and Holes

Part (2), Electron Transport:

- i. Mathematical Derivations: Electron Drift, Diffusion, and Poisson's Equation; Einstein Relation; Electron and Hole Continuity Equations
- ii. Numerically Solving Electron Transport
- iii. Diffusion
- iv. Drift
- v. Recombination: Radiative, Non-radiative, Shockley-Read-Hall Assumptions; Auger; Surface
- vi. Absorption of Light

Part (3), Applications

- i. Measuring electron transport: Spectroscopy and electronic measurement techniques
- ii. Electron transport for functional devices: E.g. *pn*-junction, Transistors, Solar Cells, Light-Emitting-Diodes, Thermoelectrics, etc.

Assignments

- **Homework**: Homework will be periodically assigned with at least 5 days of notice before the due date.
- **Midterm** (TBD)
- **Final** (4/28/2022; 3:00 - 5:00 PM)
- All assessments are cumulative.

Attendance Policy, Class Expectations, and Make-Up Policy

- Attendance of lectures is highly recommended, though not required. Course material will primarily be delivered via the lectures.
- Dates for the midterm will be announced at least 2 weeks in advance. The final exam schedule is predetermined by the registrar.
- Make-up assignments and excused absences can only be considered for those students who missed due to an acceptable reason (illness, family emergencies, military obligation, religious holidays, participation in official university activities, etc.) as listed in the undergraduate catalog. It is required that, whenever possible the student notifies the instructor about the situation in advance.
<https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx>
- Students arriving late for an exam will be given only the balance of time remaining to complete their work unless an acceptable reason (see above) is provided.

Evaluation of Grades

Assignment	Percentage of Final Grade
Homework	30%
Midterm	30%
Final	40%

More information on UF grading policy may be found at:

<https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx>

Grading Policy

Final grades will be assigned using the standard deviation (σ) method. The scale for the course will be as follows:

Percent	Grade	Grade Points
Mean + σ < Score	A	4.00
Mean + 0.67 σ < Score \leq Mean + σ	A-	3.67
Mean + 0.33 σ < Score \leq Mean + 0.67 σ	B+	3.33
Mean < Score \leq Mean + 0.33 σ	B	3.00
Mean - 0.33 σ < Score \leq Mean	B-	2.67
Mean - 0.67 σ < Score \leq Mean - 0.33 σ	C+	2.33
Mean - σ < Score \leq Mean - 0.67 σ	C	2.00
Mean - 1.33 σ < Score \leq Mean - σ	C-	1.67
Mean - 1.67 σ < Score \leq Mean - 1.33 σ	D+	1.33
Mean - 2 σ < Score \leq Mean - 1.67 σ	D	1.00
Mean - 2.33 σ < Score \leq Mean - 2 σ	D-	0.67
Score \leq Mean - 2.33 σ	E	0.00

More information on UF grading policy may be found at:

<https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx>

Instructor may lower the threshold for attaining the letter grades specified above (to the benefit of the students).

Students Requiring Accommodations

Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting <https://disability.ufl.edu/students/get-started/>. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

Course Evaluation

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at <https://gatorevals.ua.ufl.edu/students/>. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via <https://ufl.bluera.com/ufl/>. Summaries of course evaluation results are available to students at <https://gatorevals.ua.ufl.edu/public-results/>.

In-Class Recording

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A “class lecture” is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To “publish” means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

University Honesty Policy

UF students are bound by The Honor Pledge which states, “We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: “On my honor, I have neither given nor received unauthorized aid in doing this assignment.” The Conduct Code (<https://sccr.dso.ufl.edu/process/student-conduct-code/>) specifies a number of behaviors that are in violation of this code and the possible sanctions. If you have any questions or concerns, please consult with the instructor or TAs in this class.

Commitment to a Safe and Inclusive Learning Environment

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Jennifer Nappo, Director of Human Resources, 352-392-0904, jpennacc@ufl.edu
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, taylor@eng.ufl.edu
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, nishida@eng.ufl.edu

Software Use

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Student Privacy

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: <https://registrar.ufl.edu/ferpa.html>

Campus Resources:
Health and Wellness

U Matter, We Care:

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

Counseling and Wellness Center: <https://counseling.ufl.edu>, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Discrimination, Harassment, Assault, or Violence

If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **Office of Title IX Compliance**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, title-ix@ufl.edu

Sexual Assault Recovery Services (SARS)

Student Health Care Center, 392-1161.

University Police Department at 392-1111 (or 9-1-1 for emergencies), or <http://www.police.ufl.edu/>.

COVID-19

- You are expected to wear approved face coverings at all times during class and within buildings even if you are vaccinated.
- If you are sick, stay home and self-quarantine. Please visit the UF Health Screen, Test & Protect website about next steps, retake the questionnaire and schedule your test for no sooner than 24 hours after your symptoms began. Please call your primary care provider if you are ill and need immediate care or the UF Student Health Care Center at 352-392-1161 (or email covid@shcc.ufl.edu) to be evaluated for testing and to receive further instructions about returning to campus.
- If you are withheld from campus by the Department of Health through Screen, Test & Protect, you are not permitted to use any on campus facilities. Students attempting to attend campus activities when withheld from campus will be referred to the Dean of Students Office.
- UF Health Screen, Test & Protect offers guidance when you are sick, have been exposed to someone who has tested positive or have tested positive yourself. Visit the [UF Health Screen, Test & Protect website](#) for more information.
- Please continue to follow healthy habits, including best practices like frequent hand washing. Following these practices is our responsibility as Gators.

Academic Resources

E-learning technical support, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu.
<https://lss.at.ufl.edu/help.shtml>.

Career Resource Center, Reitz Union, 392-1601. Career assistance and counseling; <https://career.ufl.edu>.

Library Support, <http://cms.uflib.ufl.edu/ask>. Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring.
<https://teachingcenter.ufl.edu/>.

Writing Studio, 302 Tigert Hall, 846-1138. Help brainstorming, formatting, and writing papers.
<https://writing.ufl.edu/writing-studio/>.

Student Complaints Campus: <https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/>; <https://care.dso.ufl.edu>.

On-Line Students Complaints: <http://www.distance.ufl.edu/student-complaint-process>.