Master Course Description for EE-482/582 (ABET sheet)

Title: Semiconductor Devices

Credits: 4

UW Course Catalog Description

Coordinator: M. P. Anantram, Professor of Electrical and Computer Engineering Potential

Instructors for this course: Prof. Denise Wilson, Prof. Scott Dunham

Goals: To extend the elementary knowledge of semiconductor device physics that students have already acquired in prior courses. To provide students with a more advanced understanding of elementary band theory and the operation of important electronic devices such as pn junction diodes, metal-semiconductor contacts, MOSFETs BJTs, and memory devices. To introduce the students to simulation tools for device modeling.

Learning Objectives: At the end of this course, students will be able to:

1. *Explain* concepts in solid-state physics that are relevant to the behavior of semiconductor devices.
2. *Apply* major concepts of solid-state physics and devices to the behavior of electrons and holes in materials.
3. *Describe* the fundamentals of electron and hole flow in semiconducting materials.
4. *Formulate* and *derive* equations for electron and hole transport in semiconductors.
5. *Apply* the drift-diffusion equations and tunneling equations to the semiconducting devices.
6. *Explain the* phenomena of minority and majority carrier generation and recombination, and their transport.
7. *Understand* various physical approximations used to solve the governing equations for quantitative description of device operation.
8. *Analyze* transistor technologies from past to emerging FET (Field Effect Transistor) devices. Understand the fundamental parameters that control the *gain* in transistors.
9. *Design* a contemporary semiconducting device. Examples include nanoscale transistors, semiconducting devices for biological detection and sequencing such as IGFETs (Ion Gated FETs)
10. *Introduce* the students to semiconductor device modeling (Computer Aided Design tools).

Textbook: Ben G. Streetman and Sanjay K. Banerjee, *Solid State Electronic Devices*, 7th Ed., John Wiley & Sons, 2014.

Reference Text: Simon M. Sze, Yiming Li, Kwok K. Ng, Physics of Semiconductor Devices 4th Edition, Wiley, 2021

Laboratory Handbook: There is no lab.

Prerequisites by Topic:

1. Exploring Devices (EE 280) or Devices and Circuits 1 (EE 331) or Electronic Properties of Materials (MSE 351) or Quantum Mechanics (PHYS 324)
2. Differential equations (MATH 207) OR Accelerated [Honors] Calculus (MATH 135) OR Introduction to Differential Equations and Applications (AMATH 351)
3. This course typically has some enrollments from Physics and Material Science and Engineering Students. These students have an adequate background.

Topics:

1. **Schrodinger equation**, Particle in a box
2. **Periodic Solids**, Brillouin zone, Bloch's Theorem, Band structure from QM, Band structure of Si and GaAs (high symmetry points/lines), Direct and Indirect Semiconductors
3. **Density of States**, Fermi Distribution function
4. **Semiconductor Basics**, Concept/Properties of Holes, Electron and Hole Density, Doping, Mobility
5. **Drift-Diffusion equations**, RG, Minority Carrier Diffusion Equation (MCDE)
6. **Diodes**, Band diagram, Qualitative treatment of Avalanche and Zener
7. **Metal-Semiconductor Junctions**, band diagram, and Schottky Diodes
8. **Metal-Oxide-Semiconductor Junction**, MOS Capacitor (low and high frequency), Derivation of threshold voltage for inversion
9. **MOSFET**, Derivation of triode region, Dennard's Scaling Analysis, Short channel effects, Tunnel transistor basics
10. **LED and Solar Cell,** Basics discussed in terms of PN junction diodes.
11. **Memory Devices,** Operation principle of Flash Memory, DRAM, SRAM, Phase change memory, Resistive memory, MRAM / Magnetic memory, and so on.

Course Structure: The class meets for two lectures a week, each consisting of a 100-minute session with a break in between. There is regular homework and there is a midterm exam and a final project.

Grading: Homework (34%), midterm exam (33%), and final project (33%).

Distinguishing Graduate and Undergraduate Components: The graduate offering will involve a more difficult HW and exam. While both the undergraduate and graduate students will perform modeling for the project, the graduate students will be evaluated for introducing emerging device concepts in their project.

Computer Resources: Python, EE Linux lab, Device Simulation Software

Laboratory Resources: There is no lab in the course.

Grading: Homework, Exam, and Project are all equally weighted.

ABET Student Outcome Coverage: This course addresses the following outcomes:

(1) *Problems: An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.* Most of the lectures and homework assignments deal with: (i) translating the fundamental concepts to quantitatively describe devices with desired current-voltage characteristics; (ii) solving engineering problems by showing the students how to formulate the necessary governing equations and how to solve these equations with proper approximations guided by physical understandings of each device's operation. Relevance: High.

Religious Accommodations:

"Washington state law requires that UW develop a policy for accommodation of student absences or significant hardship due to reasons of faith or conscience, or for organized religious activities. The UW's policy, including more information about how to request an accommodation, is available at Religious Accommodations Policy (https://registrar.washington.edu/staffandfaculty/religious-accommodations-policy/). Accommodations must be requested within the first two weeks of this course using the Religious Accommodations Request form (https://registrar.washington.edu/students/religious-accommodations-request/)."

Accommodations & Access

"If you have already established accommodations with Disability Resources for Students (DRS), please communicate your approved accommodations to me at your earliest convenience so we can discuss your needs in this course. If you have not yet established services through DRS, but have a temporary health condition or permanent disability that requires accommodations (conditions include but not limited to; mental health, attention-related, learning, vision, hearing, physical or health impacts), you are welcome to contact DRS at 206-543-8924 or uwdrs@uw.edu or disability.uw.edu. DRS offers resources and coordinates reasonable accommodations for students with disabilities and/or temporary health conditions. Reasonable accommodations are established through an interactive process between the student, instructor, and DRS. It is the policy and practice of the University of Washington to create inclusive and accessible learning environments consistent with federal and state law."

Academic Integrity:

"Engineering is a profession demanding a high level of personal honesty, integrity and responsibility. Therefore, it is essential that engineering students, in fulfillment of their academic requirements and in preparation to enter the engineering profession, adhere to the College of Engineering Statement of Principles. Any student in this course suspected of academic misconduct (e.g., cheating, plagiarism, or falsification) will be reported to the

College of Engineering Dean's Office and the University's Office of Community Standards and Student Conduct to initiate the student conduct process. *Any student found to have committed academic misconduct may receive a zero for their grade on the impacted academic work (e.g., assignments, project, or exams), and academic consequences, with the possibility of expulsion."*

Title IX:

The UW, through numerous policies, prohibits sex- and gender-based violence, harassment, and discrimination and expects students, faculty, and staff to act professionally and respectfully in all work, learning, and research environments.

For support, resources, and reporting options related to sex- and gender-based violence, harassment, or discrimination, refer to the UW Title IX's website, specifically the *Know Your Rights & Resources* guide. Should you wish to make the Office of the Office of the Title IX Coordinator aware of a Title IX concern, visit the Make a Title IX Report webpage.
Please know that if you choose to disclose information to me about sex- or gender-based violence, harassment, or discrimination, I will connect you (or the person who experienced the conduct) with resources and individuals who can best provide support and options. You can also access additional resources directly:

- You can request anonymous support, from SafeCampus
- You can request confidential support, from a confidential advocate.
- If you know you want to submit a formal complaint, contact the Civil Rights Investigation Office.

Please note that some senior leaders and other specified employees have been identified as *Officials Required to Report*. If an Official Required to Report learns of possible sex- or gender-based violence, harassment, or discrimination they are required to contact the Office of the Title IX Coordinator and report all the details they have in order to ensure that the person who experienced harm is offered support and reporting options.

Relevant Websites

- Title IX: uw.edu/titleix/
- Survivor resources: uw.edu/titleix/survivor-resources/
- Confidential advocates: uw.edu/sexualassault/support/advocacy/
- SafeCampus: uw.edu/safecampus/
- Officials Required to Report: uw.edu/titleix/employee-reporting-expectations/
- Policies: uw.edu/titleix/policies/

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