

The University of New Mexico
ECE 471 – Fall 2008
Materials and Devices II

Overview

Course Catalog Description: An advanced study of the p-n junction and the more advanced concepts in transistors and optoelectronics.

Prerequisites: Materials and Devices I (EECE 371)

Textbook: D. A. Neamen, *Semiconductor Physics and Devices, 3rd Edition*, McGraw-Hill

Class Goals: The aim of this course is to provide understanding of advanced concepts in semiconductor materials and selected devices. The student will understand non-ideal aspects of p-n junctions, bipolar junction transistors, and field effect transistors, as well as the operational principles of light emitting diodes and lasers.

Course Coordinators: Prof. Stephen Hersee and Prof. Ralph Dawson

Table 1: Objectives, Implementation, and Assessment

Outcomes		Implementation	Assessment	A	B	C	D	E	F	G	H	I	J	K
O_1	Understand fundamentals of quantum mechanics & wave-particle duality, application of Schrodinger's equation to rectangular barriers, quantum wells, and the Hydrogen atom.	6 hours lecture in weeks 1-2	<ul style="list-style-type: none"> ● Homework #1 & 2 ● Exam #1 	✓	✓			✓			✓	✓	✓	
O_2	Understand energy band structure in semiconductor materials, Bloch's Theorem, effective mass, density of states functions, Fermi-Dirac statistics.	6 hours lecture in weeks 3-4	<ul style="list-style-type: none"> ● Homework #3 & 4 ● Exam #1 	✓	✓			✓			✓		✓	
O_3	Understand advanced semiconductor materials concepts: deep level impurities, non-equilibrium carrier dynamics, scattering, ambipolar transport.	7.5 hours lecture in weeks 5-7	<ul style="list-style-type: none"> ● Homework #5 & 6 ● Exam #1 	✓	✓	✓		✓						
O_4	Understand advanced concepts of the p-n junction: diffusion capacitance, generation and recombination currents, heterojunctions.	3 hours lecture in weeks 7-8	<ul style="list-style-type: none"> ● Homework #7 ● Exam #2 	✓	✓	✓		✓						✓
O_5	Understand applications of p-n homo- and hetero-junctions: light emitting diodes, lasers, high electron mobility transistors.	4.5 hours lecture in weeks 9-10	<ul style="list-style-type: none"> ● Homework #8 ● Exam #2 	✓	✓	✓		✓					✓	✓
O_6	Understand advanced concepts of bipolar junction transistors: Early effect, emitter bandgap narrowing, Kirk effect, heterojunction devices.	7.5 hours lecture in weeks 11-13	<ul style="list-style-type: none"> ● Homework #9 & 10 ● Exams #2 & 3 	✓	✓	✓		✓						✓
O_7	Understand advanced concepts of MOSFETs: threshold voltage, C-V characteristics vs. frequency, sub-threshold conduction, channel length modulation, velocity saturation.	7.5 hours lecture in weeks 13-15	<ul style="list-style-type: none"> ● Homework #11 & 12 ● Exam #3 	✓	✓	✓		✓						✓

LECTURE SCHEDULE - ECE 471 Fall 2008

<u>Week</u>	<u>Date</u>	<u>Lecture</u>	<u>Topic</u>
1	Tu 8/26	1	Administrative details Prerequisites Homework and grading policy Office hours
Quantum Mechanics			
			Background: Planck, Einstein, de Broglie Wave – particle duality Schroedinger's Equation Postulates of Quantum Mechanics Time Independent form: Separation of variables Wave packets (handout only) Group and phase velocities
	Th 8/28	2	Exclusion Principle Potential Barriers Complex Barriers 1D Infinite Quantum Well
2	Tu 9/2	3	1D symmetric finite quantum well Harmonic Oscillator
Solid State Physics			
	Th 9/4	4	Lattice Vibrations/Phonons
3	Tu 9/9	5	Energy Band Structure Bloch's Theorem Kronig-Penney Model Brillouin Zones
	Th 9/11	6	3D (real) Band structure for Si, Ge, GaAs Direct, Indirect Optical absorption
4	Tu 9/16	7	Effective mass tensor Density of states: Sommerfeld model Occupation probability – Fermi factor
Properties of Semiconductors in Equilibrium			
	Th 9/18	8	Review of intrinsic and extrinsic materials: n_i , n_o , p_o , E_f
5	Tu 9/23	9	Dopants; Fermi levels; Ellipsoidal conduction bands
Carrier Transport			
	Th 9/25	10	Drift: scattering, mobility Diffusion Velocity saturation
6	Tu 9/30		Exam #1 - QM through dopants and Fermi levels

Week Date Lecture Topic

Properties of Non-Equilibrium Semiconductors

6 Th 10/2 11 Generation and recombination
Minority Carrier Lifetime
Band to band
Traps – Brief treatment of Shockley-Read-Hall

7 Tu 10/4 12 Quasi-Fermi levels
Ambipolar transport equation
Th 10/9 13 Ambipolar transport examples

Diodes

8 Tu 10/14 14 Diode equation (review)

Th 10/16 No Class – Fall Break

9 Tu 10/21 15 Junction (depletion) and Diffusion capacitance
Injection ratio
Non-ideal effects: generation and recombination currents

Th 10/23 16 Detectors
Solar cells
p-i-n detectors
Avalanche photo-diodes

10 Tu 10/28 17 Light emitting diodes (LEDs)

Th 10/30 18 Heterojunctions
Anderson model
Depletion and accumulation regions
Notches and spikes
Grading
Injection mechanism

11 Tu 11/4 19 Lasers
Electron confinement
Beam confinement
Quantum wells
HEMTs
Superlattices
Gunn effect

MOSFETs

Th 11/6 20 MOS Capacitors
Depletion and accumulation
Oxide charge

11 Tu 11/11 **EXAM #2 - Through Gunn effect**

<u>Week</u>	<u>Date</u>	<u>Lecture</u>	<u>Topic</u>
11	Th 11/13	21	Flat band voltage Threshold voltage C-V characteristics Frequency effects
12	Tu 11/18	22	MOSFET structure Operating principles Non-ideal effects
	Th 11/20	23	I-V characteristic Non-saturation Saturation
13	Tu 11/25	24	Non-ideal effects Sub-threshold conduction Channel length modulation Mobility variation Velocity saturation
	Th 11/27		No Class – Thanksgiving Break

Bipolar Transistors

14	Tu 12/2	25	Transistor action Minority carrier Distributions
	Th 12/4	26	Current gain
15	Tu 12/9	27	Non-ideal effects Early Effect Current crowding Emitter Bandgap Narrowing Kirk effect
	Th 12/11	28	Heterojunction Bipolar Transistors
	Th 12/18		Final Exam