EE 362 Electronic, Magnetic, & Optical Properties of Materials
3-0 (3 credit hours)

Bring- pen/pencil(s), equation sheet(s)/allowed materials, calculator, and straight-edge/ruler.

Text: Semiconductor Physics and Devices: Basic Principles (4th Edition), Donald A. Neamen, McGraw Hill, 2012, ISBN 978-0-07-352958-5.

Chapter 1 The Crystal Structure of Solids

- Space lattices/crystal structures
- Bravais lattices
- Atomic volume & surface density
- Miller indices

Chapter 2 Introduction to Quantum Mechanics

- Photoelectric effect
- K.E., photon energy, work function
- eV versus Joules
- deBroglie wavelength and photon momentum
- Uncertainty Principle
- Schrodinger's Wave Equation
- Probability density function and potential barriers &/or wells
- Transmission & reflection coefficients

Chapter 3 Introduction to the Quantum Theory of Solids

- Quantized energy levels & energy bands
- Kronig-Penney Model and *k*-space diagram
- Conduction and valence bands
- Drift current density
- Electron effective mass
- Holes and hole effective mass
- Density of States Function
- Fermi-Dirac probability function and Maxwell-Boltzmann approximation

Chapter 4 The Semiconductor in Equilibium

- Electron n_0 & hole p_0 concentrations in conduction & valence bands
- Intrinsic carrier concentration $n_i = p_i$
- Intrinsic Fermi energy level E_{Fi} in relation to E_c, E_v, *and* E_{midgap}
- Dopants & ionization energy
- Fermi energy level E_F for doped/extrinsic semiconductors versus E_{Fi}
- $n_0\, p_0 = n_i^2$ product

- Ionization rate versus temperature
- Equilibrium electron and hole concentrations for doped/extrinsic semiconductors

Chapter 5 Carrier Transport Phenomena

- Drift current density
- Diffusion current density
- Carrier mobility μ and diffusion coefficient D
- Conductivity σ and resistivity ρ and resistance R
- Drift velocity v_d
- Einstein Relation relating mobility and diffusion coefficient
- Hall Effect

Chapter 6 Nonequilibrium Excess Carriers in Semiconductors

- Excess Carriers
- Recombination and generation
- Excess minority carrier lifetime
- Time-dependent diffusion equations
- Ambipolar Transport equations
- Ambipolar diffusion coefficient and mobility
- Diffusion length
- Quasi-Fermi energy levels

Chapter 7 The pn Junction

- Built-in potential barrier V_{bi}
- Thermal voltage V_t
- Depletion layer/space charge widths & maximum electric field at zero bias
- Depletion layer/space charge widths & maximum electric field w/ reverse bias
- Junction capacitance C' (F/m^2) and C (F)
- One-sided pn junctions

Chapter 8 The pn Junction Diode

- Be able to find majority and minority carrier concentrations on each side of depletion layer
- Be able to find minority carrier concentrations in p- and n-regions using ambipolar transport eq'n
- Be able to find electron J_n, hole J_p, & total J_{tot} current densities across depletion layer
- Be able to find ideal reverse saturation current density J_s across depletion layer
- Be able to find majority carrier current densities in p- and n-regions
- Small-signal diffusion conductance g_d, resistance r_d, and capacitance C_d as well as admittance Y
- Add in junction capacitance and series resistance for p- and n-regions to get complete small-signal circuit model of pn diode.

Chapter 10 Fundamentals of the Metal-Oxide-Semiconductor Field-effect-Transistor

- MOS capacitor depletion layer thickness x_d
- Potential associated with energy differences between E_F and E_{Fi}, ϕ_{fp} and ϕ_{fn}.
- Threshold potential ϕ_s and maximum depletion layer thickness x_{dT}
- Surface charge density at threshold and beyond
- Metal-semiconductor work function ϕ_{ms}, equivalent trapped charge surface density Q_{ss}', oxide capacitance C_{ox}, and flat band voltage V_{FB}
- Charge density in depletion layer at threshold $|Q_{SD}'(\max)|$ and threshold (gate) voltage V_T
- *C-V* characteristics (e.g., C'(acc), C'(depl), C'_{FB}, C'_{min}, & C'(inv)) for MOS capacitors
- n- & p-channel MOSFET saturation voltage $V_{DS}(\text{sat})$
- n- & p-channel MOSFET drain current I_D equations for linear and saturation regions
- Transconductance for linear g_m and saturation g_{ms} regions
- MOSFET substrate bias effects- change in V_T and Q_{SD}' and body effect coefficient γ
- MOSFET frequency limits

Chapter 12 The Bipolar Transistor

- Modes- active, saturation, cutoff, and inverse
- Minority carrier concentration distributions for forward-active (linear) mode
- Common-base current gain α
- Emitter injection efficient factor γ, base transport factor α_T, and recombination factor δ
- Emitter current densities and currents- J_{nE}, J_{pE}, I_{nE}, I_{pE}, J_E, and I_E
- Common-emitter current gain β
- I_C and I_B