Special Topics in Solid State for Optoelectronics

Title: **Solid State Engineering**
Course Number: **16:332:599**
Instructor: **Dr. M. A. Parker**

Description:

Solid State Electronics emphasizes fundamental concepts necessary for research and studies in solid state and optoelectronics. The course briefly reviews and examines the foundations of the quantum theory including Hilbert space and group theory concepts. Topics on symmetry and bonding culminate in the Bloch wavefunction and the formation of bands, the tight binding model, and the k-p theory. The course discusses the density of states within bulk and reduced dimensional structures (nanostructures) and develops the statistical mechanics necessary to determine the distribution of charge carriers within the bands and defect states (e.g., Fermi Dirac and Boltzman distributions). The class material includes models for electrical transport in crystalline and non-crystalline materials. The carrier and phonon distributions in conjunction with phonon-electron interaction determine the mobility and the return to thermal equilibrium. The course introduces doping, the pn junction and conduction through semiconductor heterostructure and introduces non-classical types of transport that are becoming important to increase the speed and functionality of devices, while decreasing their size and the power.

Prerequisites: The student should have the equivalent of ECE 581 with introductory quantum mechanics.

References:

1. Solid State and Quantum Theory for Optoelectronics, M. A. Parker, Draft 0 On-Line
2. Fundamentals of Semiconductors, Physics and Materials Properties, 2nd Ed., P. Y. Yu, M. Cardona, Springer, Berlin (1999).
3. Compound Semiconductor Device Physics, S. Tiwari, Academic Press, Boston (1992)
4. Quantum Phenomena, S. Datta, Addison-Wesley, Reading (1989)
5. Introduction to Solid State Physics, C. Kittel, Wiley (1995)
6. Solid State Physics, N. Ashcroft, D. Mermin, International Publishing (1976).

Course Format: Lectures, Homework

Lectures: 28 @ 4/3 hours for each.

Homework: Approximately one set of problems per week.

Tentative Class Information: 16:332:599 **Section:** Index:
Initial Class Times: T,Th 430-550
Initial Location: EE 240
Text book: Web site and handouts **Prerequisites:** ECE 581

Content

1. Introduction (1,1) *(classes for present topic, cumulative number of classes)*

Preview types of materials, bands and bandgap states, doping, electrical transport, fabrication, and growth techniques. Future trends in macroscopic, mesoscopic and microscopic components, and example nanodevices.

2. Selected Topics in Quantum Theory (6,7)

Summary of Hilbert space for vectors and operators, dual spaces, linear operators and representations, translation and rotation operators, tensor product spaces, commutators, Hermitian and unitary operators, dyadic notation. Selected topics in generalized coordinates, Lagrange and Hamiltonian formulation of classical mechanics, Poisson brackets. Review basic elements of quantum theory including collapse of the wavefunction and the density operator. As time permits, continue with multi-particle systems, spin and angular momentum, propagators and Feynman path integrals, and introduction to second quantization.

3. Crystal Structure and Phonons (5,10)

Bravais lattice, basis of atoms, crystals, reciprocal lattice, Miller indices. Phonons, dispersion curves, Brillouin zone, group velocity, density of states, phonon energy distribution, applications to specific heat. As time permits, quantization of the phonon field.

4. Conduction, Bands, States (7,17)

Review Kronig-Penny model, band diagrams, Bloch wave functions. Continue with effective mass equation, tensor effective mass, tight binding model, k-p band theory, density of states for bulk and reduced dimensional structures.

5. Equilibrium Statistics (Stat Mech) (5,22)

Entropy, derivation of Boltzmann and Fermi-Dirac statistics, Fermi Function, carrier density, doping and PN junctions.

6. Non-Equilibrium Statistics (5,27)

Return to equilibrium, transitions, distribution methods, phonon collisions, drift-diffusion equation, quasi-Fermi level.

7. Technologies (2,29) topics as time permits

Landau levels, SEEDs and the Quantum Confined Stark Effect, Aranov-Bohm effect devices, superconducting devices, quantum teleportation and quantum computing, non-demolition measurements.