EE599 – Solid State Physics of Low Dimensional Systems

University of Southern California
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Tuesday and Thursday 11:00-12:20PM
Office Hours: Thursday 11-1PM
Course Website: http://blackboard.usc.edu

Goals: This 3 unit course will cover the fundamental solid state physics necessary to understand and design modern electronic and optical devices based on nanoscale materials. A microscopic derivation of the important optical and electronic properties of these nanoscale materials will be presented. The course begins with a treatment of the electronic states. This includes the tight-binding method and $k{\cdot}p$ formalisms. Bulk materials, heterostructures and nanostructures will be treated within this formalism. Then doping and equilibrium carrier statistics will be covered. The equilibrium part of the course will be concluded with a discussion of lattice dynamics. The second part of the course will cover non-equilibrium behavior of semiconductors. Electron transport will be discussed in the framework of the Boltzmann transport equation (i.e., diffusive transport) and the Landauer formalism (i.e., ballistic transport). This discussion will include various scattering mechanisms, high field transport and transport in heterostructures. The course concludes with a discussion of the dielectric function and optical properties of semiconductors. This will include the dielectric properties of the free electron gas, the lattice, and band to band transitions, as well as Raman and photoluminescence spectroscopy.

Textbooks:

Solid State Physics, by Souza-Filho, Cronin and Dresselhaus (PDF)
Physical Properties of Carbon Nanotubes, by Saito and Dresselhaus (PDF)

Grading: There will be homework due approximately every other week during the lecture period with problems related to the lecture material. A midterm and final exam will also be given. Homework will count for 70% of your final grade and each exam will count for 15% of your final grade.

Course Outline: The course will meet for the full semester, which is 15 weeks. Depending on how quickly lecture material is covered, the following is a tentative list of topics to be covered in the class.

I. Electronic bandstructure (weeks 1-2)
   - How to calculate *E(k)* for real materials?
   - How to read “spaghetti diagrams”?
   - Crystal symmetries and momentum-space
   - Density of states calculations

II. Bulk materials, heterostructures, and nanostructures (weeks 3-4)

- Si, GaAs, quantum wells, nanowires, carbon nanotubes, graphene, and transition metal dichalcogenides (TMDCs)

III. Effective mass tensors in low dimensions (weeks 5-6)
- Quantum Wells
- Nanowires

IV. Doping and carrier statistics (weeks 7-8)
- Calculating Fermi energies without the Maxwell-Boltzmann approximation

V. Electron transport (Boltzmann equation) (weeks 9-10)
- Boltzmann Transport Equation (diffusive transport)
- Landauer Transport Equation (ballistic transport)
- Calculating electron transport in electric fields, magnetic fields, and temperature gradients (i.e., thermoelectric transport)
- A detailed review of scatting mechanisms

VI. Phonons and lattice dynamics (weeks 11-12)
- The dynamical matrix method
- Calculating phonon dispersion relations

VII. Dielectric function and optical properties (weeks 13-15)
- The dielectric function and optical absorption
- Excitons and plasmonics
- Raman scattering and photoluminescence