E3 280 January 3:0

Carrier transport in nanoscale devices

Instructor

Kausik Majumdar
Email: kausikm@iisc.ac.in

Teaching Assistant

No Teaching Assistant
Email: NA

Department: Electrical Communication Engineering (ECE)

Course Time: Tue, Thu, 08:30 AM - 10:00 AM

Lecture venue: ECE 1.07

Detailed Course Page: http://www.ece.iisc.ernet.in/~kausikm/teaching.html

Announcements

None

Brief description of the course

The course is primarily designed for M. Tech. or Ph.D. students who are beginning their career in the broad field of electronic devices. The course provides a strong background about carrier transport in electronic devices. Aspects of both semi-classical and quantum transport are discussed in details in the context of classical and modern electronic devices.

Prerequisites

A background in quantum mechanics and solid state physics is preferred, but not essential.

Syllabus

Module 1: Introduction

Module 2-5: Review of basic quantum mechanics, crystal structure and Brillouin zone, electrons in crystalline solids, momentum space, Energy band structure in semiconductors, quantum confinement, semi-classical electroc dynamics in perfect crystal.

Module 6: Scattering of electrons, Derivation of Fermi Golden Rule.

Module 7-11: Concept of scattering rate and relaxation time, scattering by ionized impurity, different types of phonon scattering and calculation of corresponding relaxation times, electron-electron scattering, electron scattering for confined carriers, surface roughness scattering.

Module 11-14: Concept of distribution function - equilibrium versus non-equilibrium, Boltzmann transport equation(BTE) - derivation and implication, Relaxation time approximation, solution of BTE, special cases, numerical solutions, validity of BTE, coupled electrical and thermal transport.

Module 15-18: Quantum transport - conduction quantization, current flow in a one-level model, different regimes of transport including self-consistent field and Coulomb blockade, current carrying modes in quantum wire and 2D electron gas, ballistic versus non-ballistic transport.

Module 19-24: Open system versus closed system, concept of level broadening, Formal treatment of open system, coherent transport using Green's function, ballistic current in a two-terminal device.

Course outcomes

The students would learn the following from this course:

(1) Brief overview of basic quantum mechanics, crystal structure and Brillouin zone, electrons in crystalline solids, momentum space, Energy band structure in semiconductors, quantum confinement, semi-classical electroc dynamics in perfect crystal.

(2) Concepts of scattering of carriers, Fermi golden rule.

(3) Different types of scattering mechanisms including Ionized impurity scattering, various phonon scattering methods, e-e scattering, surface roughness scattering, and scattering for quantum confined carriers.

(4) Concept of distribution function, Boltzmann transport equation(BTE), relaxation time approximation.

(5) Solution of BTE, numerical solutions, validity of BTE, coupled electrical and thermal transport.

(6) Quantum transport - conduction quantization, current flow in a one-level model, different regimes of transport including self-consistent field and Coulomb blockade, current carrying modes in quantum wire and 2D electron gas, ballistic versus non-ballistic transport.

(7) Open system versus closed system, concept of level broadening, Formal treatment of open system, coherent transport using Green's function, ballistic current in a two-terminal device.

Grading policy

10% for assignments,

30% for mid-term examination,

25% for project, and

35% for final examination.

Assignments

Typically assignments are grouped int two or three parts and distributed over the entire semester.

Besides, there is a project work where the students need to develop a device simulator using numerical solution to simulate transport in MOSFET.

Resources

The main resource for the course is the class notes. Apart from that, the following are useful for references in various parts of the syllabus:

Books:

M. Lundstrom, Fundamentals of Carrier Transport, Cambridge University Press.

S. Datta, Quantum Transport: Atoms to Transistors, Cambridge University Press.

A. Ghatak and S. Lokanathan, Quantum Mechanics, Trinity Press

Papers:

Various recent as well as classic papers.