

ELEG 5323: Semiconductor Nanostructures I

Catalog Description: This course is focused on the basic theoretical and experimental analyses of low dimensional systems encountered in semiconductor heterojunctions and nanostructures with the emphasis on device applications and innovations. Prerequisite: ELEG 4203 or instructor permission.

Textbook: Semiconductor Heterojunctions and Nanostructures, Omar Manasreh (McGraw-Hill, New York, 2005). ISBN 0-07-145228-1

Homework: Homework is assigned weekly except on the weeks in which tests are assigned.

Tests: Two mid-term tests and one final test. One mid-term test may be replaced by a presentation on topics related to the nanotechnology.

Topic covered:

Chapter 1. Introduction to Quantum Mechanics

1.1 Introduction

- 1.1.1 Blackbody radiation
- 1.1.2 The specific heat capacity of solids
- 1.1.3 Photoelectric effect
- 1.1.4 The Bohr model of the atom

1.2 The de Broglie Relation

1.3 Wave Functions and the Schrödinger Equation

1.4 Wave Packet at a Given Time

1.5 Separation of Variables

1.6 Dirac Notation

1.7 Important Postulates

1.8 Important Mathematical Tools

- 1.8.1 The scalar product
- 1.8.2 Linear operators
- 1.8.3 Action of a linear operator on a bra
- 1.8.4 The adjoint operator A^\dagger of a linear operator A
- 1.8.5 Eigenvalues and eigenfunctions of an operator
- 1.8.6 The Dirac δ -function
- 1.8.7 Fourier series and Fourier transform in quantum mechanics

1.9 Variational Method

1.10 Perturbation

1.11 Angular Momentum

Summary

Problems

Chapter 2. Potential Barriers and Wells

2.1 Stationary States of a Particle in a Potential Step

2.2 Potential Barrier with a Finite Height

2.3 Potential Well with an Infinite Depth

2.4 Finite-Depth Potential Well 51

2.5 Unbound Motion of a Particle ($E > V_0$) in a Potential Well with a Finite Depth

- 2.6 Triangular Potential Well
- 2.7 Parabolic Potential Well
- 2.8 Delta-Function Potentials
- 2.9 Transmission in Finite Double-Barrier Potential Wells
- 2.10 Wentzel-Kramers-Brillouin (WKB) Approximation
- 2.11 Energy Levels in Double Quantum Well Structure
- Summary
- Problems

Chapter 3. Electronic Energy Levels in Periodic Potentials

- 3.1 Bloch's Theorem
- 3.2 The Kronig-Penney Model
- 3.3 Bloch Electron in a Weak Periodic Potential
- 3.4 One-Electron Approximation in a Periodic Dirac δ -functions
- 3.5 Superlattices
- 3.6 Effective Mass
- 3.7 Band Structure Calculation Methods
 - 3.7.1 Tight-binding method
 - 3.7.2 $k \cdot p$ method
 - 3.7.3 Envelope function approximation

Summary

Problems

Chapter 4. Tunneling Through Potential Barriers

- 4.1 Transmission Through Potential Barriers
- 4.2 Tunneling Through Pyramidal Potential Barriers
- 4.3 Double-Barrier Potential
- 4.4 The pn -Junction Tunneling Diode
- 4.5 Resonant Tunneling Diodes
- 4.6 Coulomb Blockade

Summary

Problems

Chapter 5. Distribution Functions and Density of States

- 5.1 Distribution Functions
- 5.2 Maxwell-Boltzmann Statistic
- 5.3 Fermi-Dirac Statistics
- 5.4 Bose-Einstein Statistics
- 5.5 Density of States
- 5.6 Density of States of Quantum Wells, Wires, and Dots
 - 5.6.1 Quantum wells
 - 5.6.2 Quantum wires
 - 5.6.3 Quantum dots
- 5.7 Density of States of Other Systems
 - 5.7.1 Superlattices
 - 5.7.2 Density of states of bulk electrons in the presence of a magnetic field
 - 5.7.3 Density of states in the presence of an electric field

Summary

Problems

Chapter 8. Semiconductor Growth Technologies: Bulk, Thin Films, and Nanostructures

8.1 Introduction

8.2 Growth of Bulk Semiconductors

8.2.1 Liquid-encapsulated Czochralski (LEC) method

8.2.2 Horizontal Bridgman method

8.2.3 Float-zone growth method

8.2.4 Lely growth method

8.3 Growth of Semiconductor Thin Films

8.3.1 Liquid-phase epitaxy method

8.3.2 Vapor-phase epitaxy method

8.3.3 Hydride vapor-phase epitaxial growth of thick GaN layers

8.3.4 Pulsed-laser deposition technique

8.3.5 Molecular beam epitaxy growth technique

8.3.6 Metal-organic chemical vapor deposition growth technique

8.4 Fabrication and Growth of Quantum Dots

8.4.1 Nucleation

8.4.2 Fabrications of quantum dots

8.4.3 Epitaxial growth of self-assembly quantum dots

Summary

Problems