

# Contents

|                     |          |
|---------------------|----------|
| <b>Introduction</b> | <b>1</b> |
|---------------------|----------|

## Part I Semiconductor Physics

|  |          |
|--|----------|
| <b>Chapter 1 Physics and Properties of Semiconductors—A Review</b> | <b>7</b> |
|--|----------|

- 1.1 Introduction, 7
- 1.2 Crystal Structure, 8
- 1.3 Energy Bands and Energy Gap, 12
- 1.4 Carrier Concentration at Thermal Equilibrium, 16
- 1.5 Carrier-Transport Phenomena, 28
- 1.6 Phonon, Optical, and Thermal Properties, 50
- 1.7 Heterojunctions and Nanostructures, 56
- 1.8 Basic Equations and Examples, 62

## Part II Device Building Blocks

|                                       |           |
|---------------------------------------|-----------|
| <b>Chapter 2 <i>p-n</i> Junctions</b> | <b>79</b> |
|---------------------------------------|-----------|

- 2.1 Introduction, 79
- 2.2 Depletion Region, 80
- 2.3 Current-Voltage Characteristics, 90
- 2.4 Junction Breakdown, 102
- 2.5 Transient Behavior and Noise, 114
- 2.6 Terminal Functions, 118
- 2.7 Heterojunctions, 124

|   |            |
|---|------------|
| <b>Chapter 3 Metal-Semiconductor Contacts</b> | <b>134</b> |
|---|------------|

- 3.1 Introduction, 134
- 3.2 Formation of Barrier, 135
- 3.3 Current Transport Processes, 153
- 3.4 Measurement of Barrier Height, 170
- 3.5 Device Structures, 181
- 3.6 Ohmic Contact, 187

|   |            |
|---|------------|
| <b>Chapter 4 Metal-Insulator-Semiconductor Capacitors</b> | <b>197</b> |
| 4.1 Introduction, 197                                     |            |
| 4.2 Ideal MIS Capacitor, 198                              |            |
| 4.3 Silicon MOS Capacitor, 213                            |            |

Part III Transistors

|  |            |
|--|------------|
| <b>Chapter 5 Bipolar Transistors</b>       | <b>243</b> |
| 5.1 Introduction, 243                      |            |
| 5.2 Static Characteristics, 244            |            |
| 5.3 Microwave Characteristics, 262         |            |
| 5.4 Related Device Structures, 275         |            |
| 5.5 Heterojunction Bipolar Transistor, 282 |            |

|  |            |
|--|------------|
| <b>Chapter 6 MOSFETs</b>                             | <b>293</b> |
| 6.1 Introduction, 293                                |            |
| 6.2 Basic Device Characteristics, 297                |            |
| 6.3 Nonuniform Doping and Buried-Channel Device, 320 |            |
| 6.4 Device Scaling and Short-Channel Effects, 328    |            |
| 6.5 MOSFET Structures, 339                           |            |
| 6.6 Circuit Applications, 347                        |            |
| 6.7 Nonvolatile Memory Devices, 350                  |            |
| 6.8 Single-Electron Transistor, 360                  |            |

|  |            |
|--|------------|
| <b>Chapter 7 JFETs, MESFETs, and MODFETs</b> | <b>374</b> |
| 7.1 Introduction, 374                        |            |
| 7.2 JFET and MESFET, 375                     |            |
| 7.3 MODFET, 401                              |            |

Part IV Negative-Resistance and Power Devices

|                                   |            |
|-----------------------------------|------------|
| <b>Chapter 8 Tunnel Devices</b>   | <b>417</b> |
| 8.1 Introduction, 417             |            |
| 8.2 Tunnel Diode, 418             |            |
| 8.3 Related Tunnel Devices, 435   |            |
| 8.4 Resonant-Tunneling Diode, 454 |            |

|                                |            |
|--------------------------------|------------|
| <b>Chapter 9 IMPATT Diodes</b> | <b>466</b> |
| 9.1 Introduction, 466          |            |

- 9.2 Static Characteristics, 467
- 9.3 Dynamic Characteristics, 474
- 9.4 Power and Efficiency, 482
- 9.5 Noise Behavior, 489
- 9.6 Device Design and Performance, 493
- 9.7 BARITT Diode, 497
- 9.8 TUNNETT Diode, 504

## **Chapter 10 Transferred-Electron and Real-Space-Transfer Devices 510**

- 10.1 Introduction, 510
- 10.2 Transferred-Electron Device, 511
- 10.3 Real-Space-Transfer Devices, 536

## **Chapter 11 Thyristors and Power Devices 548**

- 11.1 Introduction, 548
- 11.2 Thyristor Characteristics, 549
- 11.3 Thyristor Variations, 574
- 11.4 Other Power Devices, 582

### Part V Photonic Devices and Sensors

## **Chapter 12 LEDs and Lasers 601**

- 12.1 Introduction, 601
- 12.2 Radiative Transitions, 603
- 12.3 Light-Emitting Diode (LED), 608
- 12.4 Laser Physics, 621
- 12.5 Laser Operating Characteristics, 630
- 12.6 Specialty Lasers, 651

## **Chapter 13 Photodetectors and Solar Cells 663**

- 13.1 Introduction, 663
- 13.2 Photoconductor, 667
- 13.3 Photodiodes, 671
- 13.4 Avalanche Photodiode, 683
- 13.5 Phototransistor, 694
- 13.6 Charge-Coupled Device (CCD), 697
- 13.7 Metal-Semiconductor-Metal Photodetector, 712
- 13.8 Quantum-Well Infrared Photodetector, 716
- 13.9 Solar Cell, 719

|  |            |
|--|------------|
| <b>Chapter 14 Sensors</b>  | <b>743</b> |
| 14.1 Introduction, 743   |            |
| 14.2 Thermal Sensors, 744  |            |
| 14.3 Mechanical Sensors, 750   |            |
| 14.4 Magnetic Sensors, 758   |            |
| 14.5 Chemical Sensors, 765   |            |
| <br>   |            |
| <b>Appendixes</b>  | <b>773</b> |
| A. List of Symbols, 775  |            |
| B. International System of Units, 785                                      |            |
| C. Unit Prefixes, 786  |            |
| D. Greek Alphabet, 787   |            |
| E. Physical Constants, 788   |            |
| F. Properties of Important Semiconductors, 789                             |            |
| G. Properties of Si and GaAs, 790  |            |
| H. Properties of SiO <sub>2</sub> and Si <sub>3</sub> N <sub>4</sub> , 791 |            |
| <br>   |            |
| <b>Index</b>   | <b>793</b> |